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INTERIM MEASURE / INTERIM REMEDIAL ACTION FOR GROUNDWATER AT THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

• Environmental Restoration •
Rocky Flats Environmental Technology Site

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EXECUTIVE SUMMARY

The purpose of this Interim Measure/Interim Remedial Action (IM/IRA) Decision Document is to identify accelerated actions for remediation of shallow groundwater contamination at the Rocky Flats Environmental Technology Site (RFETS or Site). RFETS is a U.S. Department of Energy (DOE) facility, located approximately 16 miles northwest of Denver, Colorado. The Site was formerly used to produce nuclear weapons components and is now undergoing decommissioning and environmental remediation, prior to its conversion into a National Wildlife Refuge.

Although the shallow groundwater at RFETS, which constitutes the upper hydrostratigraphic unit (UHSU) at the Site, is not utilized as a source of drinking water, it can present a potential exposure pathway to the ground surface via seeps and groundwater discharge to surface water. The majority of UHSU groundwater is not contaminated, nor do areas of groundwater contamination extend to the Site boundary. However, there are areas within the Site's Industrial Area (IA) and Buffer Zone (BZ) with measured elevated concentrations of groundwater contaminants. These areas are the subject of accelerated remedial actions proposed in this IM/IRA. Groundwater at the Present Landfill and Original Landfill at RFETS is not addressed in this Groundwater IM/IRA; groundwater in those areas is addressed in their specific IM/IRAs.

The current regulatory agreement governing accelerated actions for groundwater is the Rocky Flats Cleanup Agreement (RFCA), which was adopted on July 19, 1996 and modified on June 9, 2003. RFCA outlines the goals, objectives, processes, and procedures used for Site remediation. The RFCA accelerated action approach emphasizes conducting accelerated actions to achieve early reduction of risk caused by areas of contaminated groundwater.

This IM/IRA presents a multistep process used to define groundwater contaminants of interest and identify areas that require remediation. The evaluation process described in this IM/IRA focuses on Remedial Action Objectives (RAOs) that are based on surface water standards and risk-based Surface Water Preliminary Remediation goals (SWPRGs). The RAOs are consistent with the Action Level Framework (ALF) outlined in RFCA. The RAOs are also anticipated to guide the final Site remedy for contaminated groundwater, thereby making the proposed accelerated actions consistent with the long-term goals, as well as near-term goals, for remediation of the RFETS groundwater.

The first major step in the process to determine accelerated actions for groundwater is to identify the specific groundwater contaminants, or Analytes of Interest (AOIs), to be evaluated. A three-step screening process was used to identify the AOIs. Screen 1 involved a review of historic UHSU data and investigations dating back to 1986, and involving more than 200 constituents and over 1,200 sampling locations. Based on the review, the groundwater analytes, or categories of analytes, determined to most likely adversely impact RFETS surface water quality are volatile organic compounds (VOCs), nitrate, and uranium. Screen 2 involved reviewing VOC, nitrate, and uranium groundwater data and screening out 32 VOCs that were never historically detected above

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their respective surface water standards. Screen 3 involved eliminating analytes that were not detected in contiguous, mappable plumes. Based on this screening process, the following 10 AOIs were identified for further evaluation:

- VOCs:
  - 1,1-Dichloroethene (1,1-DCE);
  - Carbon tetrachloride (CT);
  - Chloroform (CF);
  - cis-1,2-Dichloroethene (cis-1,2-DCE);
  - Methylene chloride (MC);
  - Tetrachloroethene (PCE);
  - Trichloroethene (TCE);
  - Vinyl chloride (VC);
- Nitrate; and
- Uranium.

From a transport perspective, the AOIs migrate differently in groundwater. For example, nitrate is generally transported at the same rate as groundwater flow because it is a conservative constituent and is not readily attenuated. In contrast, VOCs and uranium are subject to various attenuation mechanisms, and typically migrate at slower rates than the groundwater flow.

The AOI screening process did not identify plutonium (Pu), americium (Am), or metals as groundwater AOIs. Although Pu and Am are detected in surface soil and surface water at RFETS, those radionuclides are primarily transported as insoluble particulates by surface erosion processes. Therefore, groundwater does not play a significant role in the transport of Pu or Am at RFETS. Groundwater metals data reveal that metals at RFETS do not form distinct areas of groundwater contamination.

After identifying the AOIs, the second major step in the Groundwater IM/IRA process involved identifying areas of the Site with elevated concentrations of one or more AOIs in groundwater that could potentially require an accelerated action. In addition to evaluating groundwater data for the AOIs, subsurface soil and surface water data were also evaluated. The purpose of reviewing data for the other environmental media was to determine where pathways exist for AOIs to be transported from subsurface soil to groundwater to surface water. The review was performed to identify areas where contaminant sources in the subsurface soil contribute to groundwater contamination, where groundwater contaminants impact surface water, and where accelerated actions are potentially necessary to protect surface water from groundwater contaminants.

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Based on the evaluation of the nature and extent of the AOIs, 15 groundwater contaminant plumes were initially identified; 13 of these were determined to warrant further evaluation (areas that could potentially require an accelerated action). The two plumes eliminated from further consideration at this stage were areas near Buildings 443 and 991. Further evaluation in these areas was determined to not be necessary because (1) the fuel oil released to the ground at Building 443 is isolated, is not mobile in groundwater, and does not indicate an effect on surface water quality; and (2) the AOIs in the Building 991 area were measured at low relative concentrations with a limited spatial extent in groundwater.

The third major step in the Groundwater IM/IRA process involved further evaluating the 13 areas identified as possibly requiring an accelerated action. For this third step, three RAOs, from the Groundwater and Soil Remedial Action Objectives Technical Memorandum, were used as evaluation criteria. The RAOs are anticipated to guide the long-term remedy for the Site groundwater. Therefore, the accelerated actions will achieve the near-term goal of risk reduction for human health and the environment and at the same time be consistent with the anticipated long-term remedy for the Site. Based on the RAOs, screening of groundwater data for the AOIs was performed. The three AOI screens involved:

1. Evaluating Area of Concern (AOC) boundary well concentrations against the corresponding surface water standard for each AOI;

2. Evaluating each groundwater contamination area to assess whether it is adjacent to surface water (i.e., either colocated with a seep or adjacent to a surface water body) and if any AOIs were measured at concentrations greater than 10 times their SWPRG; and

3. Evaluating each groundwater contamination area to determine whether it impacts the beneficial use of surface water (i.e., causes surface water quality to not meet the surface water standard for any of the AOIs).

Based on analysis of the RAO screening results, seven groundwater contamination areas were identified that warrant an alternatives analysis. Some of the areas are adjacent to one another and can be combined, because they will be addressed together with an accelerated action. As a result, the five general areas that required an alternatives analysis are:

- Carbon Tetrachloride Plume (Individual Hazardous Substance Site [IHSS] 118.1);
- East Trenches Plume (IHSS Group 900-12)(downgradient portion of plume);
- Solar Evaporation Ponds (SEP) Plume (IHSS 101) (downgradient portion of plume);
- Mound Site/Oil Burn Pit #2 Plumes (IHSSs 113/153) (downgradient portions of plumes); and
- 903 Pad/Ryan's Pit Plumes (IHSSs 112/109).

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The final step of the IM/IRA process involved performing an accelerated action alternatives analysis for the five areas identified above. Remediation strategies evaluated included:

- Soil source removal;
- In-situ enhanced biodegradation (utilizing amendments injected into the groundwater to enhance biodegradation);
- Phytoremediation (involving planting deep-rooted tree species to intercept groundwater and retard contaminant migration); and
- Passive groundwater collection and treatment (using groundwater collection trenches and treatment galleries).

The results of the alternatives analysis are listed below:

- Carbon Tetrachloride Plume area – Soil source removal and in-situ enhanced biodegradation;
- East Trenches Plume (downgradient portion of plume) – Phytoremediation;
- SEP Plume (downgradient portion of plume) – Phytoremediation;
- Mound Site/Oil Burn Pit #2 Plumes – Soil source removal/excavation with in-situ enhanced biodegradation; and
- 903 Pad/Ryan's Pit Plumes – To be determined based on current investigation; will utilize either soil removal or in-situ enhanced biodegradation.

Performance monitoring was chosen to be consistent with the Fiscal Year (FY) 2005 Integrated Monitoring Plan (IMP). This performance monitoring consists of both groundwater and surface water monitoring.

In summary, the accelerated actions proposed in this IM/IRA were developed to be consistent with the RFCA objective of promoting early reduction of risk to human health and the environment associated with groundwater contamination and its potential impact on surface water. In addition, the areas identified for accelerated actions were selected based on RAO decision criteria, which are anticipated to guide the long-term remedy for the Site.

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ACRONYMS

AAESE	Accelerated Action Ecological Screening Evaluation
AL	Action Level
ALARA	As Low As Reasonably Achievable
ALF	Action Level Framework
Am	americium
AOC	Area of Concern
AOI	Analyte of Interest
APEN	Air Pollutant Emission Notice
AR	Administrative Record
ARAR	Applicable or Relevant and Appropriate Requirement
BMP	Best Management Practice
BZ	Buffer Zone
CAD/ROD	Corrective Action Decision/Record of Decision
CAH	chlorinated aliphatic hydrocarbon
CCR	Code of Colorado Regulations
CDH	Colorado Department of Health
CDPHE	Colorado Department of Public Health and Environment
CEARP	Comprehensive Environmental Assessment and Response Program
CERCLA	Comprehensive Environmental, Response, Compensation, and Liability Act
CF	chloroform
CFR	Code of Federal Regulations
CHWA	Colorado Hazardous Waste Act
CID	Cumulative Impacts Document
cm/sec	centimeters per second
COC	Contaminant of Concern
CT	carbon tetrachloride
CRA	Comprehensive Risk Assessment
CWA	Clean Water Act
CWQC	Colorado Water Quality Control
D&D	Decontamination and Decommissioning
DCE	dichloroethene

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DNAPL	dense non aqueous phase liquid
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DOT	U.S. Department of Transportation
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ER RSOP	Environmental Restoration RFCA Standard Operating Protocol for Routine Soil Remediation
ESA	Endangered Species Act
ET	evapotranspiration
FY	Fiscal Year
FS	Feasibility Study
gpm	gallons per minute
HASP	Health and Safety Plan
HI	Hazard Index
HRC	Hydrogen Release Compuond
HRR	Historical Release Report
HSL	Hazardous Substance List
IA	Industrial Area
IAG	Interagency Agreement
ICP/MS	inductively coupled plasma/mass spectrometry
IGD	Implementation Guidance Document
IGMP	Installation Generic Monitoring Plan
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
IMP	Integrated Monitoring Plan
ITS	Interceptor Trench System
JHA	Job Hazard Analysis
K-H	Kaiser-Hill Company, L.L.C.
LDR	Land Disposal Restrictions
LHSU	lower hydrostratigraphic unit
LRA	Lead Regulatory Agency
MCL	maximum contaminant level

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Pu	plutonium
PU&D	Property Utilization and Disposal
QA	Quality Assurance
QC	Quality Control
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RFA	Rocky Flats Alluvium
RFCA	Rocky Flats Cleanup Agreement
RFCAB	Rocky Flats Citizens Advisory Board
RFCAB	Rocky Flats Council of Local Governments
RFETS or Site	Rocky Flats Environmental Technology Site
RI	Remedial Investigation
RSOP	RFCA Standard Operating Protocol
SEP	Solar Evaporation Ponds
SID	South Interceptor Ditch
SME	Subject Matter Expert
SPP	Solar Ponds Plume
SSMP	Site-Specific Monitoring Plan
SPPTS	Solar Ponds Plume Treatment System
SVOC	semi-volatile organic compound
SWD	Soil Water Database
SWMU	Solid Waste Management Unit
SWPRG	Surface Water Preliminary Remediation Goal
SWWB	Site-Wide Water Balance
TAL	Target Analyte List
TCA	trichloroethane
TCE	trichloroethene
TCL	Target Compound List
TDS	Total Dissolved Solids
TIC	tentatively identified compound
TOC	Total Organic Carbon
TRU	transuranic
TU	Temporary Unit
µg/l	micrograms per liter
UBC	Under Building Contamination

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this Interim Measure/Interim Remedial Action (IM/IRA) Decision Document is to identify accelerated actions for remediation of shallow groundwater contamination at the Rocky Flats Environmental Technology Site (RFETS or Site). Although shallow groundwater is not used as a source of drinking water at RFETS, it can present a potential exposure pathway if contaminated groundwater discharges to the ground surface, at seeps or directly into surface water bodies. The accelerated actions proposed in this document are intended to reduce potential risks to human health and the environment caused by contaminated groundwater migration and its potential effect on surface water quality.

The need for an accelerated action to manage groundwater contamination is based on an evaluation of several data sources, including groundwater and surface water sample data, groundwater modeling results, and subsurface soil data pertinent to potential sources of shallow groundwater contamination. Previously completed accelerated actions for groundwater quality are also taken into consideration. The accelerated actions proposed in this document are interim measures intended to expedite remedial work and maximize early risk reduction at the Site. While the proposed accelerated actions are expected to achieve early risk reduction, they are also evaluated against Remedial Action Objectives (RAOs) that are anticipated to be those established for the final remedy for contaminated shallow groundwater.

This IM/IRA was prepared in accordance with guidance outlined in Appendix B of the Rocky Flats Cleanup Agreement (RFCA) Implementation Guidance Document (IGD)(DOE et al., 1999). It is subject to approval by the U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE) after public review and comment.

1.2 General Site Description

RFETS is a U.S. Department of Energy (DOE) facility located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver, that was formerly used to process and manufacture nuclear weapons components. The Site occupies approximately 6,240 acres. It includes a developed Industrial Area (IA), where manufacturing operations took place on approximately 300 acres, and a Buffer Zone (BZ) that surrounds the IA. The BZ is largely undeveloped, and occupies approximately 6,000 acres (Figure 1-1).

Currently, RFETS is undergoing decommissioning and environmental remediation actions to achieve cleanup in accordance with RFCA (DOE et al., 1996). Upon completion of these activities (generally referred to as Site closure), jurisdiction and control over most of the RFETS land will be transferred to the U.S. Fish and Wildlife Service (USFWS) to be operated as the Rocky Flats National Wildlife Refuge.

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1.3 Scope

This IM/IRA addresses contamination in shallow groundwater of the Upper Hydrostratigraphic Unit (UHSU) beneath the IA and adjacent BZ at RFETS. The majority of shallow groundwater in the UHSU, in terms of spatial extent, is not contaminated, nor do contaminated groundwater plumes extend to the Site boundary. The UHSU consists of the Rocky Flats Alluvium (RFA), Valley Fill Alluvium (VFA), colluvium, the underlying weathered bedrock claystones, and the Arapahoe No. 1 Sandstone (see Section 2.5 for detail on the RFETS hydrogeology). Accelerated actions proposed in this IM/IRA target contamination in identifiable plumes in shallow UHSU groundwater that indicate contamination has migrated over time and may continue to migrate in the future.

A large fraction of the infiltrating precipitation at the Site is lost to evapotranspiration (ET), based on results from an integrated hydrologic model of RFETS (K-H, 2002a). The relatively small portion of the infiltrating precipitation that does become shallow groundwater, and is available to transport contaminants in areas where groundwater contamination is found, ultimately discharges to surface water as seeps, or directly to streams or ponds, before reaching the eastern Site boundary. Therefore, UHSU groundwater that has been impacted by Site activities, both in the IA and BZ, discharges to surface water prior to leaving RFETS.

Deeper groundwater, defined as the Lower Hydrostratigraphic Unit (LHSU), is not evaluated in this IM/IRA. The LHSU is composed of the unweathered Arapahoe, Laramie, and Fox Hills Formations. The upper Laramie Formation claystones of the LHSU, with low permeability, act as an effective aquitard that restricts downward vertical groundwater flow from the UHSU to the LHSU. Therefore, contaminants in the shallow groundwater of the UHSU, which exist because of historic Site activities, are restricted by the LHSU from migrating deeper and reaching the underlying Laramie-Fox Hills aquifer (Hurr, 1976; RMRS, 1996; K-H, 2004a).

Groundwater in the Present Landfill and Original Landfill areas is not addressed in this Groundwater IM/IRA. Groundwater in those areas is addressed in the specific IM/IRAs for the Present Landfill (K-H, 2004b) and Original Landfill (IM/IRA pending approval). Although select figures in this document show the Present Landfill and Original Landfill for reference, evaluation of groundwater data or accelerated actions for those areas is not presented in this document.

1.4 Regulatory Framework and Approach

RFCA is both a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) federal facility agreement and a Resource Conservation and Recovery Act/Colorado Hazardous Waste Act (RCRA/CHWA) order that governs CERCLA response actions and RCRA/CHWA corrective actions and closure actions at the Site. RFCA outlines the goals, objectives, processes, and procedures that are used for the Site remediation. Accelerated actions for RFETS groundwater are governed by RFCA.

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Under RFCA, DOE is required to perform the required remediation activities, subject to oversight and approval by the EPA and CDPHE, in accordance with their respective statuary and regulatory authority. RFCA terminated and superseded the preceding federal facility agreement and order between DOE, EPA, and CDPHE, known as the 1991 Interagency Agreement (IAG) (DOE, et al., 1991). Remediation and extensive investigations of groundwater contamination have occurred before and under the IAG and RFCA, as discussed in Section 3.2.1.

RFCA also delineates a consultative, accelerated action approach for the Individual Hazardous Substance Sites (IHSSs), Under Building Contamination (UBC) areas, and Potential Areas of Concern (PACs) (herein collectively termed IHSSs). Paragraph 79 of RFCA provides, in part ... "To expedite remedial work and maximize early risk reduction at the Site, the Parties intend to make extensive use of accelerated actions to remove, stabilize, and/or contain IHSSs. Focusing on IHSSs rather than OUs [Operable Units] will allow most remedial work to be reviewed and conducted through one of the accelerated review and approval processes described in Part 9, rather than the RI/FS process..."

The RFCA accelerated action approach emphasizes prioritizing actions for the individual IHSSs and conducting accelerated actions on contaminated soil or other sources that may contribute to plumes of contaminated groundwater. Contaminant sources that have or could potentially result in identifiable shallow groundwater contamination were identified within designated IAG or RFCA OUs or as IHSSs. However, identifiable groundwater contaminant plumes were not designated as OUs or IHSSs in either the IAG or RFCA. Groundwater contamination has historically been addressed as a component of an IHSS accelerated action (e.g., contaminated soil or buried drum removal) or in some instances on a plume basis (e.g., barrier wall, collection, and treatment). Many decisions for evaluating and remediating contaminated groundwater have been deferred to the Site-wide evaluation in this IM/IRA.

The RFCA Attachment 2, Action Levels and Standards Framework (ALF), delineates tiered groundwater Action Levels (ALs), based on Maximum Contaminant Levels (MCLs) developed by EPA for drinking water. Tier I ALs are designed to identify high concentration groundwater "sources" that should be addressed through accelerated actions. Tier II ALs are designed to prevent surface water from exceeding surface water standards/ALs by triggering groundwater management actions when necessary. Groundwater contamination above Tier I and Tier II ALs is described and evaluated in the RFCA Annual Groundwater Monitoring Reports (1997a; 1998a; 1999a; 2000a; 2001a; 2002b; 2004a).

The accelerated actions proposed in this document are intended to maximize early risk reduction at the Site and address areas of significant groundwater contamination in a manner that is consistent with the ALF tiered approach. However, the evaluation process described in this IM/IRA focuses on Remedial Action Objectives (RAOs) anticipated to guide the final Site remedy for contaminated groundwater. These RAOs are based on surface water standards and risk-based values, but are consistent with the ALF tiered approach for groundwater ALs (see Section 3.5 for a comparison of these values).

Therefore, the accelerated actions proposed in this IM/IRA are intended to protect near-term surface water quality, as well as human health and the environment, for anticipated future uses of the Site.

1.5 Groundwater Contaminants Addressed by This IM/IRA

Groundwater contaminants evaluated in this IM/IRA are volatile organic compounds (VOCs), nitrate, and uranium. These analytes were identified as the constituents with the greatest potential to cause adverse impacts to surface water quality, based on a collective understanding of RFETS groundwater contamination gained from investigations dating back to 1986, and from data collected from over 1,200 monitoring wells. From the initial list of numerous contaminants identified to warrant evaluation, 10 Analytes of Interest (AOIs) were selected as groundwater contaminants to be further evaluated (see Section 3.0). The AOIs were identified based on their observed concentrations measured in subsurface soil and groundwater samples, as well as the formation of contaminant plumes and their potential to adversely impact surface water quality.

The 10 AOIs addressed in this document are:

- VOCs:
  - 1,1-Dichloroethene (1,1-DCE);
  - Carbon tetrachloride (CT);
  - Chloroform (CF);
  - cis-1,2-Dichloroethene (cis-1,2-DCE);
  - Methylene chloride (MC);
  - Tetrachloroethene (PCE);
  - Trichloroethene (TCE);
  - Vinyl chloride (VC);
- Nitrate (N); and
- Uranium (U).

Sources of RFETS groundwater contamination are documented in the Historical Release Report (HRR) and its updates (see Section 2.3). While plutonium (Pu) and americium (Am) are contaminants in surface soil and surface water at RFETS, these radionuclides are primarily transported as insoluble particulates by surface erosion processes. Therefore, groundwater in the RFETS environment does not play a significant role in the transport of Pu or Am (K-H, 2002c), and these analytes are not addressed in this document.

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In terms of spatial extent, groundwater AOIs with the largest areal distribution of elevated concentrations are the VOCs, particularly PCE, TCE, and CT. In addition, the natural degradation by-products of those VOCs, including cis-1,2-DCE, VC, CF, and MC, are detected at varying concentrations across the Site, although natural degradation occurs at a very slow rate (K-H, 2004c).

From a transport perspective, the AOIs behave differently in the environment. Nitrate is considered a conservative constituent, because it is not readily sorbed (i.e., retarded), and generally migrates at the same rate as groundwater flow. However, in heavily vegetated areas, nitrate may be taken up by plants, which may influence its overall transport behavior (Drever, 1988). In contrast, both the VOCs and uranium are subject to various attenuation mechanisms (e.g., sorption, dispersion, degradation, diffusion, volatilization, and plant uptake) and generally migrate at a slower rate than groundwater.

1.6 Remedial Action Objectives

Consistent with the RFCA objectives[1], a near-term goal of this IM/IRA is to implement accelerated actions that promote early risk reduction. Early risk reduction is achieved by mitigating exposure pathways that present the most immediate potential hazard to human health, such as possible incidental contact with groundwater contamination by a Wildlife Refuge Worker (WRW). Another near-term goal is to implement accelerated actions that mitigate the migration of groundwater contaminants. Achieving the near-term goals facilitates the intermediate- and long-term goals to cost-effectively reduce risks posed by groundwater contamination. In particular, the groundwater strategy adopted in this IM/IRA, consistent with RFCA objectives, provides for long-term protection of surface water quality.

Domestic use of groundwater at RFETS is not anticipated and will be prevented through appropriate institutional controls. No other mechanism for human exposure to on-site groundwater is foreseen. The following RAOs, from the Groundwater and Soil Remedial Action Objectives Technical Memorandum (K-H, 2004d), are applied as evaluation criteria for this IM/IRA:

- "Meet groundwater quality standards, which are the surface water action levels and standards in ALF Table 1, at 'area of concern' (AOC) boundary wells;"
- "Groundwater that exits at seeps must achieve 1×10^{-5} risk or Hazard Index of 1 or less to WRW and not pose significant risk of adverse ecological effects;" and

[1] The RFCA Attachment 5 ALF, section 1.3, Action Prioritization and Implementation, states: "Accelerated actions will be supportive of the Intermediate and Long-Term Site Conditions as discussed in the RFCA Preamble and to the extent practicable, will contribute to the efficient performance of any anticipated long-term remedial actions. Protection of all surface water uses with respect to fulfillment of the Intermediate and Long-Term Site Conditions will be the basis for making soil and groundwater accelerated action decisions. Accelerated actions will also be designed to prevent adverse impacts to ecological resources and groundwater consistent with the ALF."

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- "Restore contaminated groundwater that discharges to surface seeps or directly to surface water as baseflow, and that is a significant source of surface water, to its beneficial use of surface water protection wherever practicable in a reasonable timeframe.'

Using the RAOs as decision criteria, a multistep process was used to determine which areas of the Site require an accelerated action to remediate groundwater contamination. That process is presented in Section 5.0. A diagram of the entire IM/IRA document, which outlines the process that starts with selecting groundwater AOIs and culminates with selecting proposed accelerated actions for groundwater, is shown on Flow Chart 1-1.

Ecological risks are not evaluated in this document. However, ecological risks related to groundwater (e.g., at seeps where groundwater discharges to the surface) will be evaluated in accordance with the Accelerated Action Ecological Screening Evaluation (AAESE). That evaluation will provide a determination regarding the need for an accelerated action to address risks to ecological receptors (K-H, 2004e). If an accelerated action is necessary to protect an ecological receptor, the action will be evaluated and proposed in a separate decision document, such as the Environmental Restoration (ER) RFCA Standard Operating Protocol for Routine Soil Remediation (ER RSOP) (K-H, 2003b).

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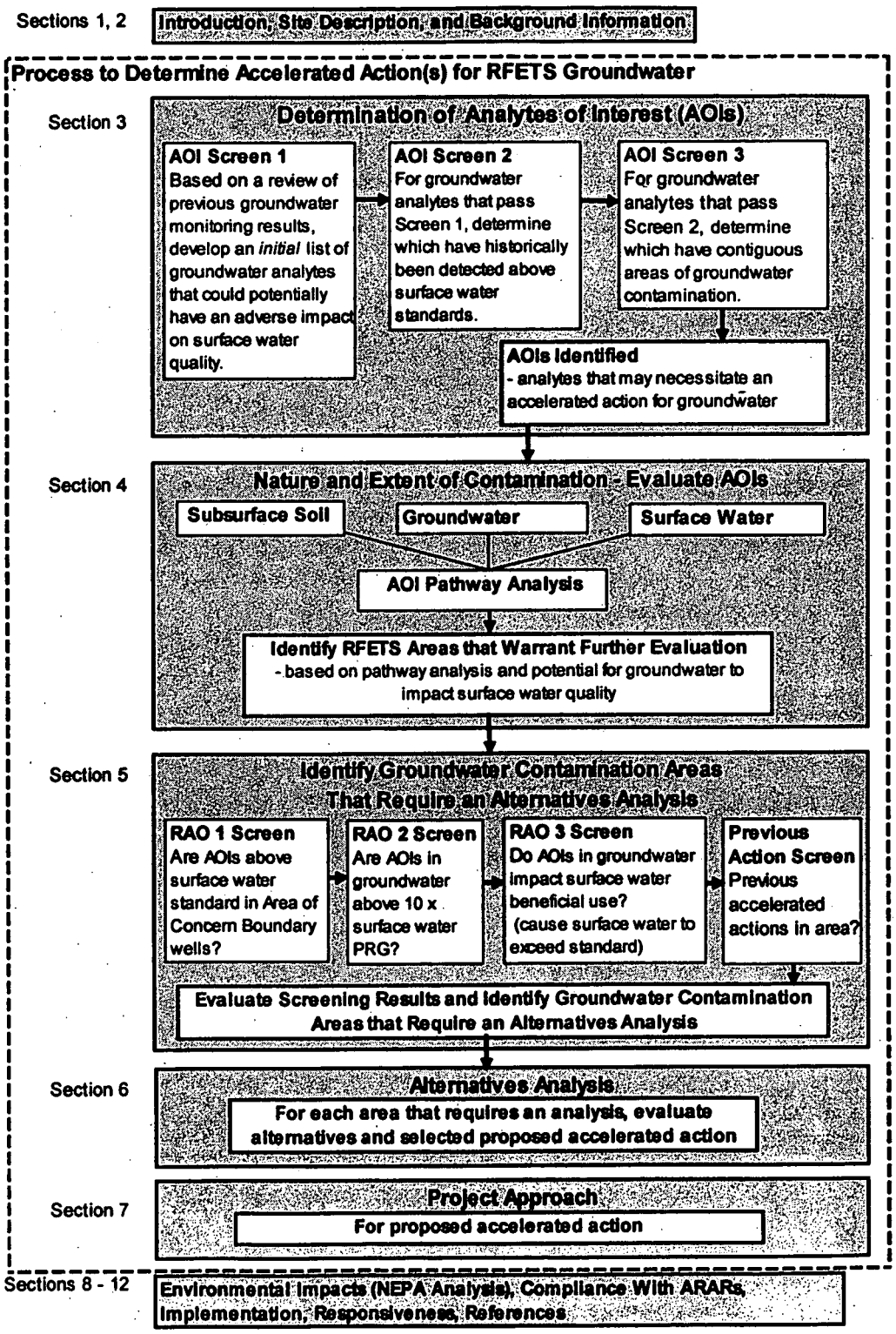
Flow Chart 1-1. Summary of the Groundwater IM/IRA Document



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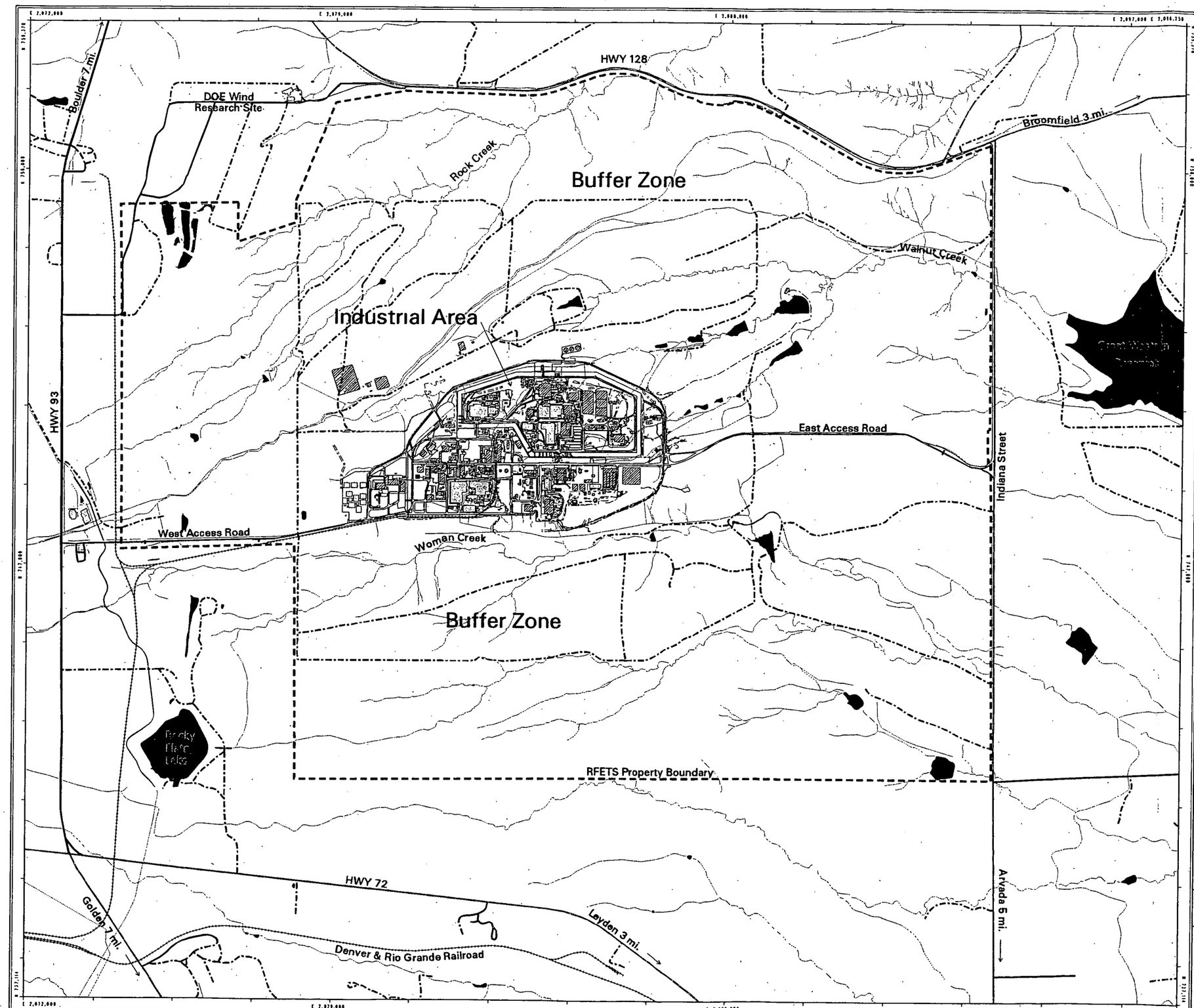

Figure 1-1

Rocky Flats Environmental Technology Site Map

Groundwater IM/IRA

EXPLANATION

Standard Map Features

- Buildings and other structures
- Demolished buildings and Other Structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats Environmental Technology Site boundary
- Heavy duty paved roads
- Medium duty paved roads
- Light duty paved roads
- Dirt roads
- Railroads

N

Scale = 1 : 26980
1 inch represents approximately 2248 feet

500 0 1000 2000ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: CH2MHILL

Prepared for: KAISER•HILL COMPANY

November 28, 2004

NT_Svr w:/projects/rfea/fy02/projects/02-0781/fig1-1_v1.aml

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2.0 SITE DESCRIPTION AND BACKGROUND INFORMATION

2.1 Site Description and Operations

Construction of the Rocky Flats Plant was initiated in 1951 and was part of the nationwide nuclear weapons research, development, and production complex. Processing and fabrication of weapons-related components began in 1952. The plant produced metal components for nuclear weapons from plutonium, uranium, beryllium, and stainless steel. Other production activities included chemical recovery and purification of recyclable transuranic radionuclides, metal fabrication and assembly, and related quality control functions. Research and development programs involved metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics. Manufactured parts were shipped off-site for final assembly. Production operations continued through 1989, except for fabrication of stainless steel components that continued in one building through the early 1990s.

Although environmental protection measures were established during operations and were generally implemented in a manner consistent with prudent environmental management at that time, some historic activities resulted in contamination of the Site, including groundwater. Efforts to document the extent of Site contamination became a major environmental focus in the 1980s and continue today, in accordance with RCRA, CERCLA, and RFCA.

2.2 Expected Site Condition at Completion of Active Remediation

After remedial actions at RFETS are complete, the IA configuration will be very different than it has been for the past fifty years. Changes to the Site will impact groundwater flow and transport of contaminants. These changes must be taken into consideration when evaluating the alternatives and accelerated actions described in this document.

To accomplish Site remediation and prepare RFETS for future use as a National Wildlife Refuge, structures will be removed, including structures below grade if they are within 3 feet of the final ground surface. An exception is structures that serve an ongoing purpose, such as groundwater collection and treatment systems, which will remain after completion of Site closure activities (see Section 4.6).

Essentially all asphalt roads and parking lots will be removed and the IA will be regraded and reseeded as necessary. Ditches, storm water conveyances, and ponds will be eliminated or reconfigured to meet desired surface stability and storm water flow performance goals. This activity is generally guided by and described in the Environmental Assessment and Finding of No Significant Impact, Pond and Land Configuration, DOE/EA – 1492 (DOE, 2004a).

Additional aspects of the Site closure configuration relevant to groundwater include the following:

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- Subsurface pipes (storm drains, sanitary sewer lines, and foundation drains) will be removed and/or disrupted to inhibit preferential pathways for groundwater. Some foundation drains may remain in place for groundwater control;
- Utility trenches and utility backfill material will not be disrupted in most cases;
- The ground surface will be regraded based on the final topographic surface provided in the land configuration project;
- Impervious materials at the ground surface will be removed;
- Structures shallower than 3 feet below grade will be removed;
- Fill material (i.e., concrete rubble) for the deep basements will range in size from gravel to cobbles. Fill material for shallow excavations is expected to be fill dirt with generally the same characteristics as the native soil;
- Concrete structures left in place below grade have low permeability (water does not readily penetrate the concrete);
- Original Process Waste Lines (OPWLs) within 3 feet of the ground surface will be removed. The remainder will be foamed or grouted in-place to the extent practicable to ensure that no pathway to surface water will be present;
- New Process Waste Lines (NPWLs) within 3 feet of the ground surface will be removed. The remainder will be clean closed under RCRA and left in-place with the ends grouted. All NPWL segments that cannot be clean closed will be removed; and
- Ponds A-1 and A-2 in the North Walnut Creek drainage and Ponds B-1, B-2, B-3, and B-4 in the South Walnut Creek drainage will be reconfigured to have lower dams, with flow passing through a notch in the modified dams.

Integrated groundwater fate and transport modeling was conducted for the IA and east-central BZ. The objective of the modeling was to predict future Site conditions, potential climatic conditions, and areas where contaminants will migrate based on various closure scenarios.

When closure of RFETS is complete, land use restrictions are anticipated that will prohibit the following: (1) residential, industrial, and commercial land use (with the possible exception of a visitor center and/or museum); (2) surface water or groundwater as sources for potable water supply; and (3) agricultural use, including any farming, raising livestock, or producing crops, vegetables, or fruits.

2.3 Documented Historical Source Areas

Historical records of known or suspected chemical releases to the environment are documented in the HRR and its subsequent updates. The HRR was updated quarterly

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until 1996, then annually from 1996 to the present, and represents the best known compilation of environmental release information at RFETS (DOE, 1992, 1993, 1994a, and 1995; K-H, 1996a, 1997b, 1998b, 1999b, 2000b, 2001b, 2002d, and 2003b). Contaminant releases documented in the HRR date back to 1952, when Site operations began. Updated reports include new or newly discovered releases, as well as any additional information gathered regarding previous releases.

In preparation for developing a computer model to simulate VOC transport in groundwater at RFETS (see Section 4.4.4), HRR source information was reviewed and Site Subject Matter Experts (SMEs) were consulted (K-H, 2004f). The HRR and subsequent updates were reviewed for mention of potential or verified releases of solvents, chemicals, PCBs, fuel, oil/grease, or process waste. More than 360 documented releases were reported in the HRR, although not all were associated with VOCs.

The releases entered in the database were classified as Priority 1, 2, or 3. A release was categorized as a Priority 1 if a large volume release was documented (greater than 100 gallons), or if the release was considered significant by Site SMEs. Smaller releases (less than 100 gallons) were categorized as Priority 2. Very small releases, considered insignificant (e.g., 0.5 gallon ethylene glycol spilled in a parking lot and cleaned up immediately), were classified as Priority 3 releases. Priority 1 and 2 releases were scrutinized during the review process. Priority 3 releases were not reviewed extensively, because the associated release volume was small and likely did not result in a release to groundwater, though all releases discussed in the HRR will be dispositioned as appropriate. Locations of the Priority 1 and 2 releases were widely distributed across the Site, as shown on Figure 2-1.

2.4 Geologic Setting

The Site is situated approximately two miles east of the Front Range of Colorado on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Spencer, 1961). The IA is located on a pediment covered by alluvium. The surface of the alluvium slopes to the east at 1 to 2 degrees. Most of the surrounding BZ is prominently dissected with intermittent streams.

Haun and Kent (1965) have summarized the geologic history of the Colorado Rocky Mountain region, which includes the Site area. Several comprehensive studies (e.g., Hurr, 1976; EG&G, 1991a, 1995a, and 1995b) have been undertaken to characterize the geology and hydrogeology at RFETS. A brief summary of results from these investigations is presented in the following subsections; the reader is referred to the above references for more detailed information.

A large amount of lithologic and stratigraphic information has been obtained for RFETS from interpretation of aerial photographs, field geologic mapping, coal and aggregate mine development, petroleum exploration, and the completion of approximately 2,000 on-site boreholes and monitoring wells.

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2.4.1 Stratigraphy

RFETS is located on a broad, eastward-sloping pediment surface along the western edge of the Denver Basin. The Site is directly underlain by unconsolidated clastic deposits (e.g., the RFA, Verdos Terrace Alluvium, and undifferentiated colluvium) that unconformably overlie bedrock (see Figure 2-2). Bedrock formations immediately underlying the alluvium include the Arapahoe and Laramie Formations. The Arapahoe and Laramie Formations are underlain by the Fox Hills Sandstone and Pierre Shale, which, because of their steeply east-dipping structural configuration, are only exposed in shallow quarries west of the Site. The unconsolidated surficial deposits, combined with the weathered portion of subcropping bedrock formations, form the UHSU and have the greatest importance concerning groundwater flow and contaminant transport at the Site. A generalized lithologic section for the Rocky Flats area is shown in Figure 2-3.

2.4.2 Structure

Structurally, the Site is located approximately two miles east of the steeply dipping strata along the western flank of the Denver Basin. The Denver Basin, a north-south trending, asymmetrical basin containing Paleozoic, Mesozoic, and Cenozoic strata, occurs on the eastern flank of the Front Range uplift. Steeply dipping Pennsylvanian to Cretaceous bedrock formations underlying RFETS are exposed at the surface and in stream valleys west of the Site. The bedrock formations are unconformably overlain by the Quaternary RFA and Verdos Alluviums, colluvium, and other unconsolidated sedimentary deposits of Recent age.

The local structure beneath RFETS has been assessed in numerous studies summarized in the Geologic Characterization Report for the RFETS (EG&G, 1995a). Several faults have been identified in the vicinity of RFETS using seismic and stratigraphic techniques, including the low-angle Golden thrust fault west of the Site. These faults have been interpreted to be of Laramide and younger age and tectonic or syndepositional in origin. Based on seismic, drilling, and trenching data, these faults are thought to have been inactive for at least one million years. None of these faults appear to extend into or offset the overlying RFA or Verdos Alluvium.

Other faults have been inferred, but not extensively characterized, at the Site based on lineaments and other structures found during drilling and excavation. These features are also confined to the bedrock formations and do not appear to be active. Current information indicates that both the known and inferred faults are confined to the bedrock formations and do not influence groundwater flow or contaminant transport in the UHSU at the Site.

2.5 Hydrogeology

Groundwater flow at the Site occurs in unconsolidated geologic materials and in subcropping weathered bedrock claystones and sandstones of the UHSU. The UHSU is considered to be the equivalent of the uppermost "aquifer," although in many areas on-site the amount of water available is insufficient to meet the aquifer definition according

to 40 Code of Federal Regulations (CFR), Section 260.10. Seeps occur on hillslopes at the contact of the surficial deposits and the underlying, less permeable UHSU bedrock. Unweathered bedrock of the LHSU underlies the UHSU. The LHSU is separated and hydraulically isolated from the UHSU by low-permeability claystones (RMRS, 1996). Background geochemical characterization of the UHSU and LHSU, based on major ion and stable isotope chemistry, has revealed that these units have different groundwater chemistry, which provides further evidence of their hydraulic isolation from each other (EG&G, 1993a and 1995b).

2.5.1 Groundwater Occurrence and Conceptual Model

The Site is located in a regional groundwater recharge area (EG&G, 1991a). UHSU groundwater recharge occurs from the infiltration of incident precipitation and as base flow along the upgradient portion of the Site drainage basin that extends west to Coal Creek. Direct precipitation either infiltrates into permeable soil or becomes overland runoff. As the infiltrating precipitation redistributes downward through the unsaturated zone, a relatively large percentage is subsequently lost through ET (K-H, 2002a). This loss increases near streams because groundwater is shallow and vegetation density increases. The remaining portion of infiltrating precipitation continues downward and eventually recharges the UHSU groundwater.

Groundwater flows from the pediment toward the drainages and discharges from the UHSU to streams and seeps. In the upper pediment areas, groundwater flows downward from unconsolidated material into and along weathered bedrock. As groundwater flows from the pediment to hillslope areas, water levels typically descend into the weathered bedrock (implying a downward vertical gradient) due to thinning unconsolidated material and increased ET effects. This causes groundwater velocities to decrease because of lower weathered bedrock hydraulic conductivities within claystone. Alternately, groundwater may preferentially flow within the Arapahoe No. 1 Sandstone, which occurs locally within the weathered bedrock. Flow through this material will increase groundwater flow velocities. In lower hillslope areas or near-stream areas, vertical hydraulic gradients typically reverse and cause an upward vertical gradient from the weathered bedrock into the unconsolidated material.

As shown on Figure 2-4, UHSU groundwater flow within the IA is strongly affected by various industrial features (K-H, 2002a). Subsurface utilities (e.g., storm, sanitary, and building foundation drains), building basements, surface pavement and routing, and building roofs affect both surface and subsurface flows in the IA. As groundwater flows from the IA down to nearby streams in the BZ, it is increasingly controlled by the hillslope structure. Important features here include the unconsolidated material-weathered bedrock interface, vegetation distribution, and the spatial distribution of hydrogeologic features as shown on Figure 2-5.

2.5.2 Groundwater Flow Directions – Current Conditions

The general groundwater flow direction is from west to east, with local variations from the pediment down to surface water drainages. Groundwater flow is predominantly

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controlled by the topography of the bedrock surface. Groundwater preferentially flows horizontally through unconsolidated material because its permeability is higher than the weathered bedrock.

In the western part of the Site, where the thickness of the RFA may exceed 100 feet, the depth to the water table is 50 to 70 feet below ground. The depth to groundwater generally becomes shallower, and the saturated thickness thinner, from west to east across the Site as the alluvial material thins and the underlying claystones are closer to the ground surface.

The potentiometric surface of the UHSU groundwater (water table surface) has been interpreted for the second and fourth quarters of calendar year 2003 and is shown on Figure 2-6 and Figure 2-7, respectively. The periods illustrated, spring and fall quarters, represent the times of year when water levels are expected to be highest and lowest, respectively. As can be seen from these figures, significant areas of unsaturated alluvium exist. In these areas, the UHSU groundwater is found in the weathered bedrock, which may include the Arapahoe No. 1 Sandstone. The areas of unsaturated alluvium have grown in size between 2001 and 2003 and include, south of Buildings 460 and 444, near the 903 Pad and Ryan's Pit, north and northeast of the Solar Evaporation Ponds (SEPs), around Building 881; immediately south and west of the B-Series ponds; and south of the Landfill Pond (K-H, 2004f). The increase in unsaturated alluvium may be due to the drier conditions observed over the past few years, the dewatering effect of groundwater collection systems (for the SEPs and near B-Series ponds), and the fact that the IA is losing less water to the hydrologic system as plant operations cease.

2.5.3 Groundwater Flow – Future Conditions

The generalized UHSU groundwater flow for the proposed RFETS reconfiguration was determined through the use of an integrated hydrologic model (K-H, 2002a and 2004f). The simulated modeling results indicate that closure-condition groundwater flow velocities change little from the current configuration. This is because hillslope morphology (surface and bedrock topography) strongly controls groundwater flow directions at RFETS. Model estimates of future groundwater flow directions are shown on Figure 2-8 as arrows. Note that the magnitude of the arrows does not correspond to a flow velocity.

The overall change in flow directions is not significant compared to the influence of hillslopes, although local increases in groundwater levels will be greatest near buildings with deep foundation drains that were assumed to be deactivated (Buildings 371, 771, 881, and 991). As a result, local flow gradients in these areas will change from toward the drains to follow hillslope and bedrock morphologies. Groundwater flow gradients will also change in the borrow area west of Building 371. Along South Walnut Creek, groundwater flow directions will change east of Building 991, and where the proposed South Walnut Creek channel will be re-engineered to eliminate roadways, fenced areas, and associated culverts. Local flow directions near the Mound Site Plume Treatment System (MSPTS) are expected to change slightly due to this proposed reconfiguration.

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The integrated hydrologic modeling produced a three-dimensional groundwater flow field of the closure configuration and was used to identify areas where groundwater will daylight at surface discharge areas. Simulated post-closure groundwater levels increase throughout the model area due to the proposed land reconfiguration. In some surface discharge areas, groundwater will discharge to three of four modified streams in the IA (the drainage between Buildings 371 and 771, the drainage along South Walnut Creek south of Building 991, and in the drainage west of Building 371). Average climate conditions will lead to seeps being present only in the drainage between Buildings 371 and 771.

Results of the integrated modeling indicate groundwater discharge to several areas, including the surface drainage west of Building 771 due to shallow bedrock and the Arapahoe No. 1 Sandstone in the area. Although the Arapahoe No. 1 Sandstone is only present as shallow, discontinuous lenses throughout the model area and has no connection to the much deeper regional confined aquifer (i.e., the Laramie/Fox Hills Aquifer), it is more permeable than the surrounding claystone/siltstone matrix and controls local groundwater flows.

For a typical climate, the model indicates some groundwater will discharge into the South Walnut Creek drainage north and downgradient of the MSPTS. This discharge area will increase during precipitation events. Southeast and downgradient of the Ryan's Pit area, the model indicates groundwater discharge will also occur at the South Interceptor Ditch (SID) and Woman Creek, but only during larger precipitation events. The integrated flow model did not simulate groundwater discharge to other areas of South Walnut Creek, although this probably occurs, for example to Pond B-2.

Discharge frequency and rates were also calculated by the model, but the model did not simulate groundwater discharge to North Walnut Creek, Woman Creek, or South Walnut Creek in the B-Series ponds area. The Site-Wide Water Balance (SWWB) model was used to predict actual discharge locations, rates, and frequency in these areas; however, the original SWWB closure scenario configuration was updated to reflect the proposed land reconfiguration as of January 2003.

2.5.4 Groundwater/Surface Water Interactions

Surface flow consists of overland flow and channelized flow. Impervious areas generate runoff almost immediately. If precipitation rates are high enough, surface soil becomes saturated and generates additional runoff, although this response is delayed compared to impervious areas. In addition, groundwater can also discharge at the ground surface (seeps), which produces more overland flow. Baseflow in some of the perennial reaches is partially sustained by groundwater discharge. Seeps are common along hillslopes at the Site (Figure 2-9) and occur along the contact between the RFA (or other unconsolidated surficial unit) and underlying claystones of the Arapahoe/Laramie Formations, and where the Arapahoe/Laramie Formation sandstones crop out. Seeps commonly appear as wet areas, even when precipitation has not occurred recently. These areas may be marked by the presence of phreatophytes (plant species with roots that extend to the water table).

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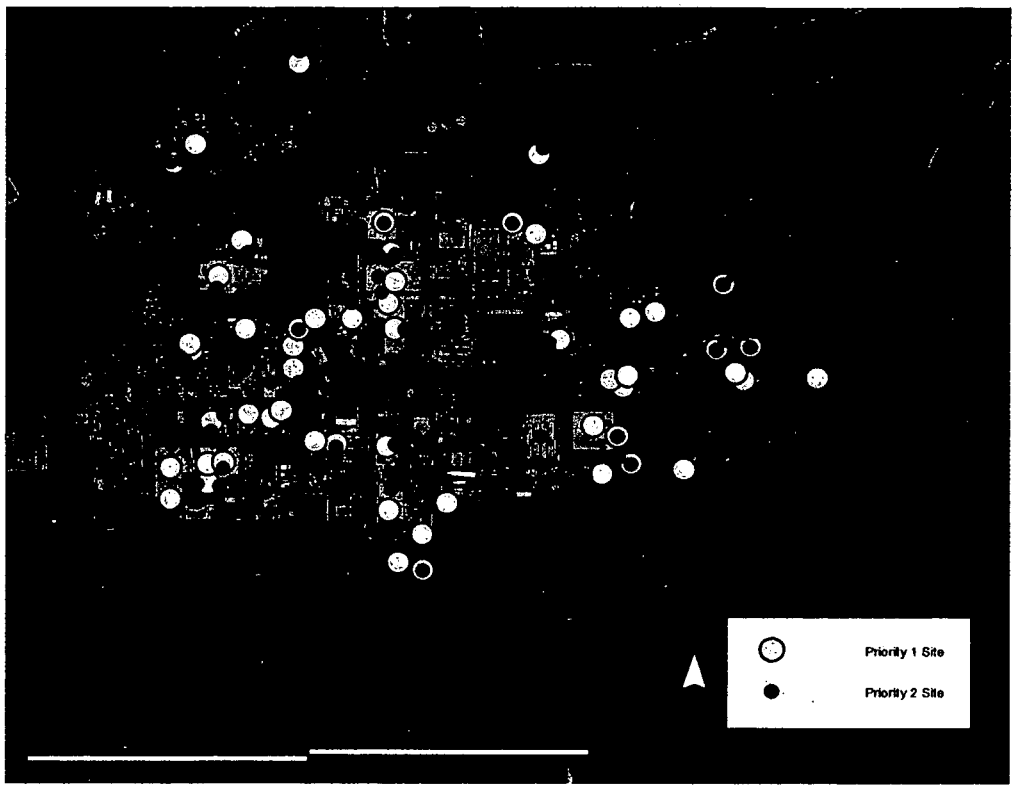
Rapid stream flow response is caused by high-intensity, low-duration precipitation events typical of the Front Range and RFETS. Overland flow and surface runoff collect in streams and eventually are either routed to on-Site ponds or off-site via Woman or Walnut Creeks. Runoff from the IA is ultimately routed to the terminal ponds, which are keyed into bedrock and therefore also intercept alluvial flow in the channels. Downstream of the terminal ponds, the stream flow largely responds to managed releases of pond water. During periods of no precipitation, surface flows and pond stage heights decline to levels dictated by groundwater discharge. Groundwater discharges to surface water mostly from subsurface utilities (e.g., foundation drains) or as direct baseflow to creeks. During warmer months, ET reduces groundwater discharge to the creeks, and can result in cessation of stream flow.

As groundwater nears stream areas, the effect of ET increases dramatically due to shallower groundwater levels and increased vegetation. Modeling results suggest that VOC losses via ET are significant, although direct field-based evidence is limited. In addition, ET losses are only high during warmer months, implying that VOC concentrations in groundwater discharges could be higher during colder months, depending on local flow conditions.

Figure 2-1. VOC Releases to the Environment Documented in the HRR



Note: Priority 1 releases are those greater than 100 gallons; Priority 2 releases are less than 100 gallons, but greater than an insignificant (0.5 gallon) Priority 3 release. (Figure Source: K-H, 2004f)

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Geologic Units

- Qv Verdos Alluvium
- Qrf Rocky Flats Alluvium
- Ka Arapahoe Formation
- Kl Laramie Formation
- Kfh Fox Hills Sandstone
- Kp Pierre Shale/Hygiene Member
- Kn Niobrara Formation
- Kb Benton Shale
- Kd Dakota Group
- Jm Morrison Formation
- TRPl Lykins Formation
- PIPf Lyons & Fountain Formations
- pЄ Undivided Igneous & Metamorphic Units

Structural interpretation from EG&G, 1993a.

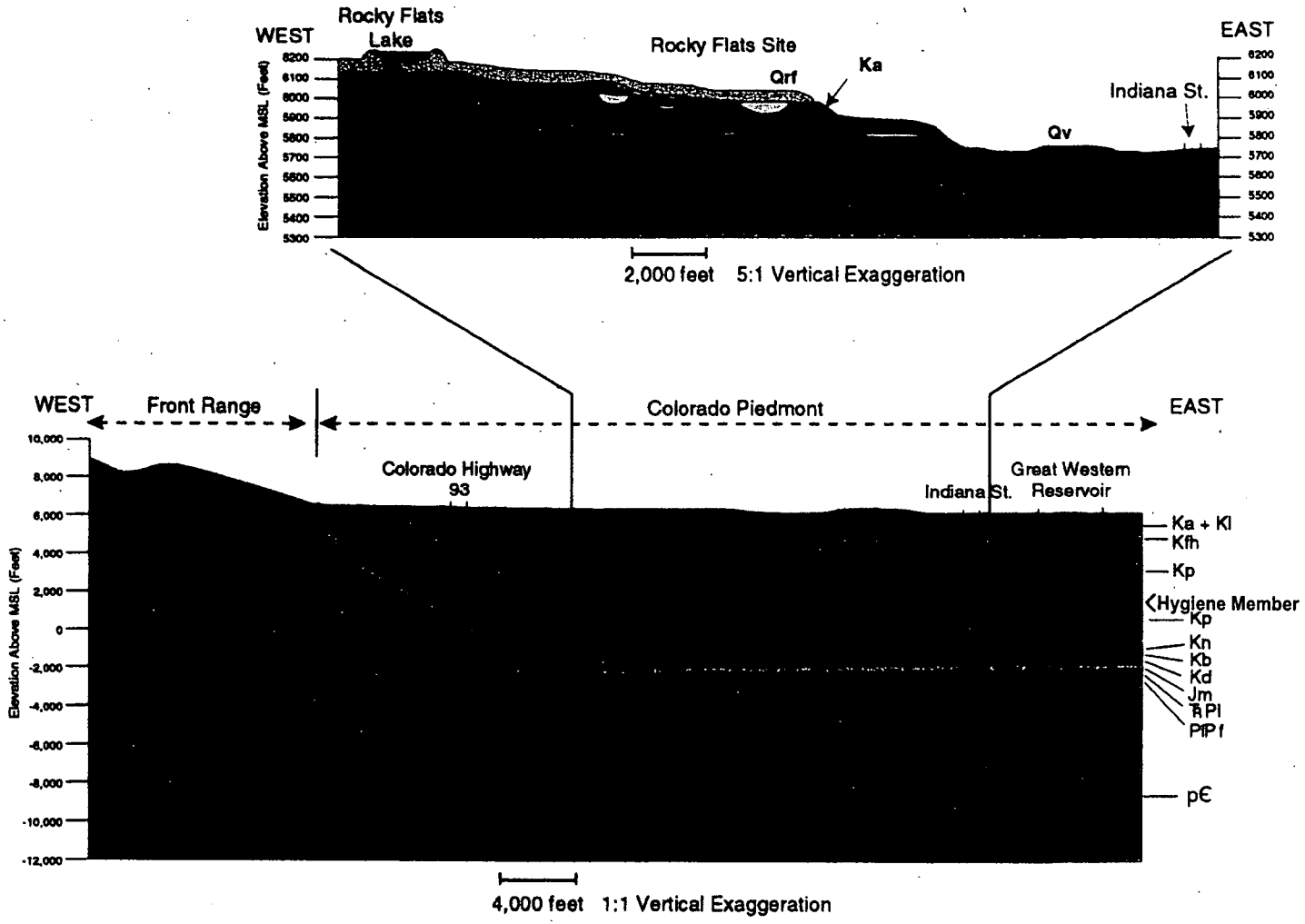


Figure 2-2
Generalized Geologic Cross Section of the Front Range and the Rocky Flats Area

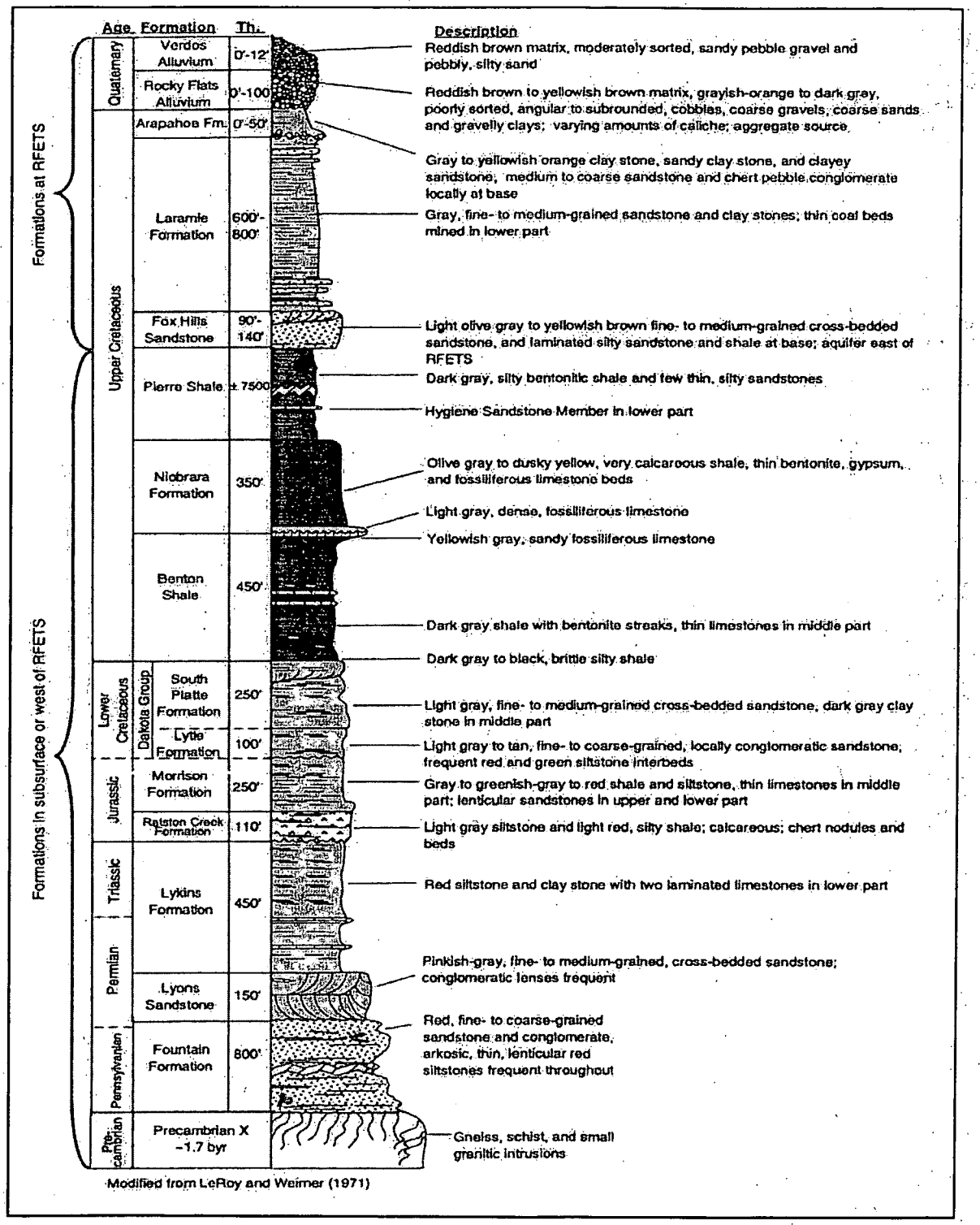
Groundwater IM/IRA

CH2MHILL

Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464 Golden, CO 80402-0464

Projects/fy2002/02-0781/fig1-4.cdr

Figure 2-3. Generalized Stratigraphic Column for the Rocky Flats Area



Modified from LeRoy and Weimer (1971)

Figure 2-4. Integrated Groundwater-Surface Water Conceptual Flow Model for the IA

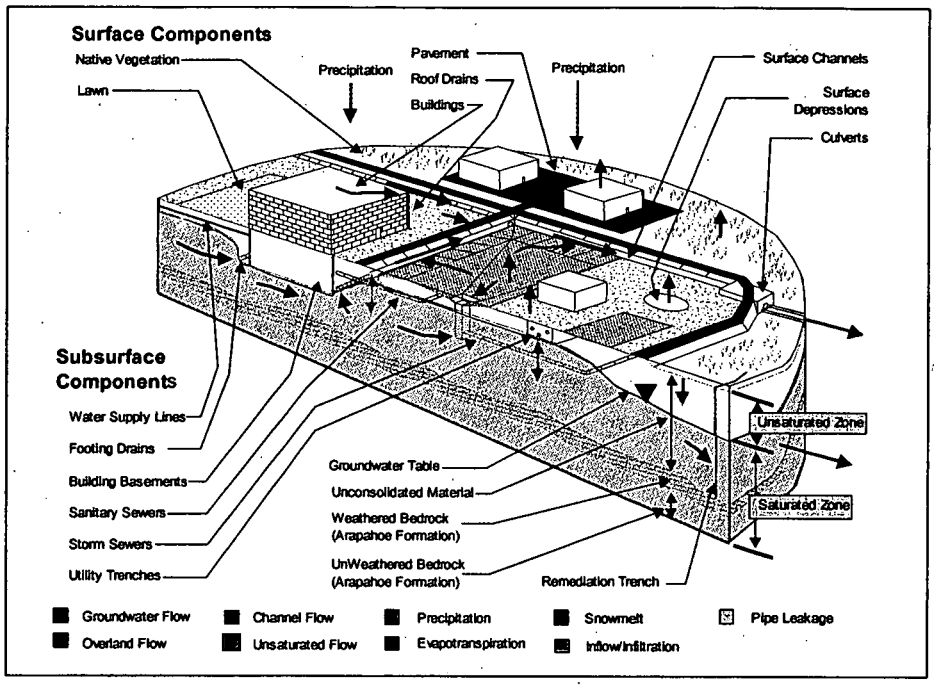
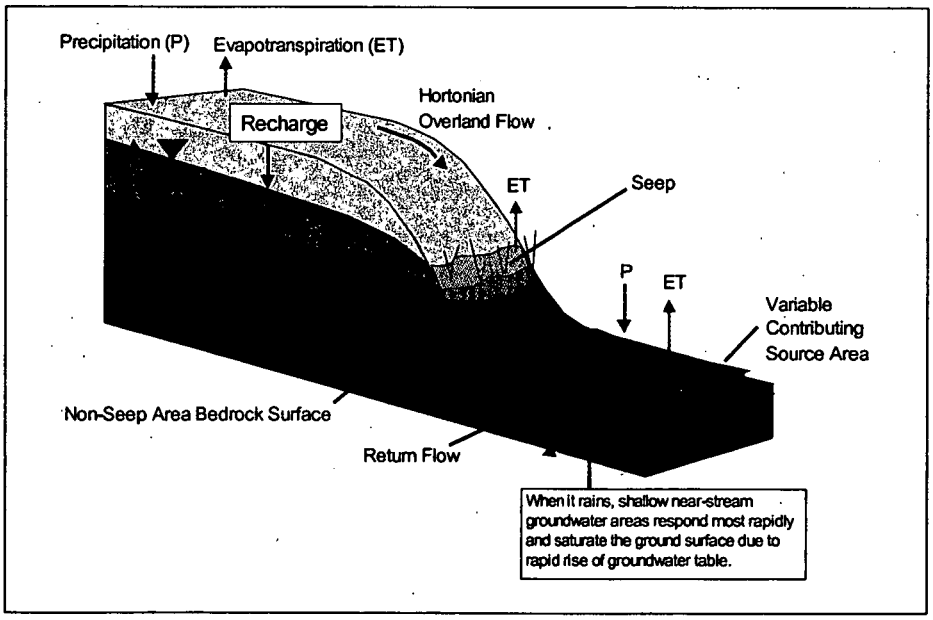


Figure 2-5. Conceptual Hillslope Flow Model



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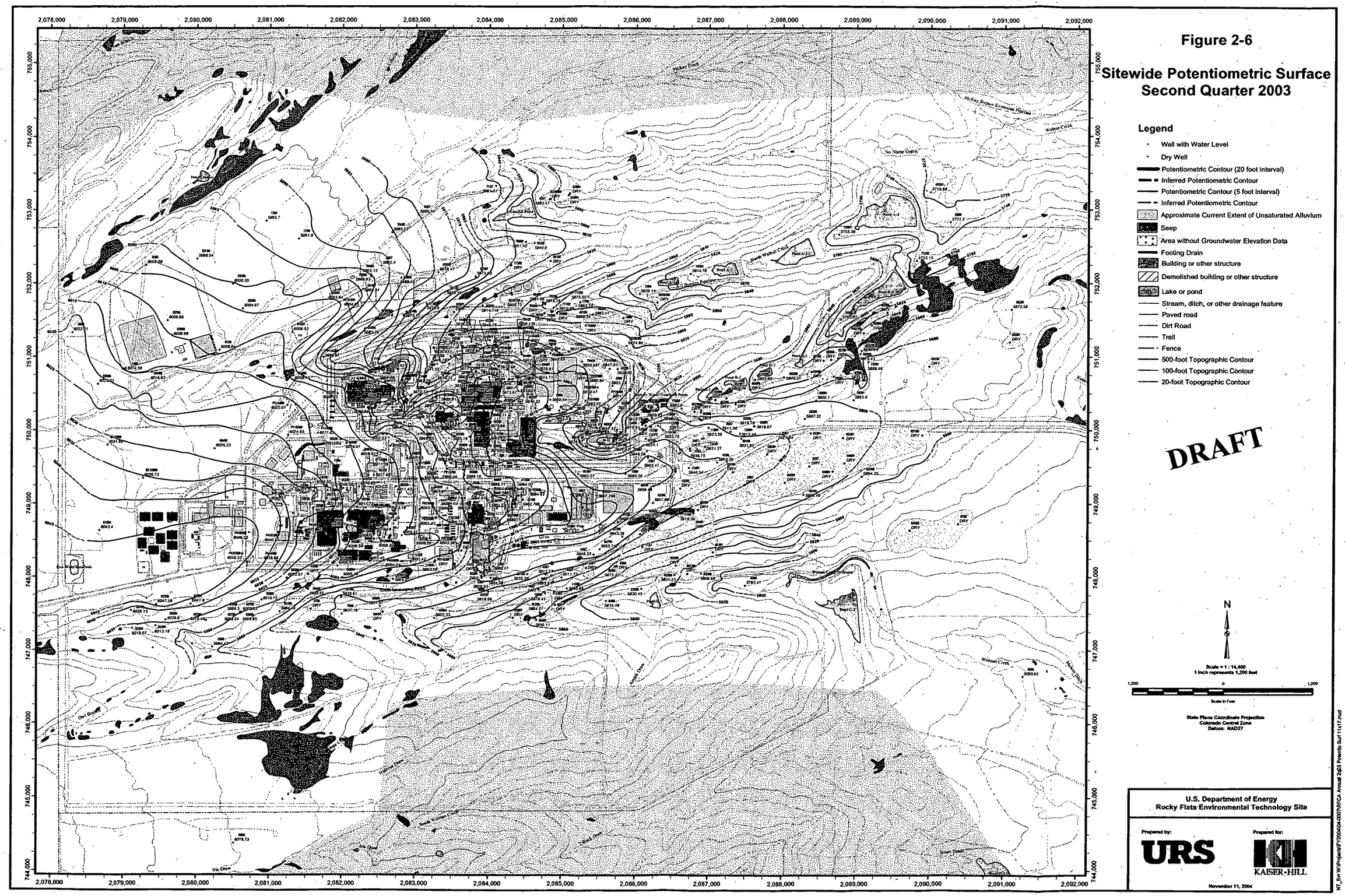
Figure 2-6
Sitewide Potentiometric Surface
Second Quarter 2003
Legend
Well with Water Level
Dry Well
Potentiometric Contour (20 foot interval)
Inferred Potentiometric Contour
Potentiometric Contour (5 foot interval)
Inferred Potentiometric Contour
Approximate Current Extent of Unsaturated Alluvium
Seep
Area without Groundwater Elevation Data
Footing Drain
Building or other structure
Demolished building or other structure
Lake or pond
Stream, ditch, or other drainage feature
Paved road
Dirt Road
Trail
Fence
500-foot Topographic Contour
100-foot Topographic Contour
20-foot Topographic Contour
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Scale = 1 : 14,400
1 inch represents 1,200 feet
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Scale in Feet
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27
U.S. Department of Energy
Rocky Flats Environmental Technology Site
Prepared by:
URS
Prepared for:
KAISER•HILL
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No Name Gulch
Walnut Creek
North Walnut Creek
Owl Branch
Iris Drive
Indian Creek
Woman Creek
South Walnut Creek
Smart Ditch

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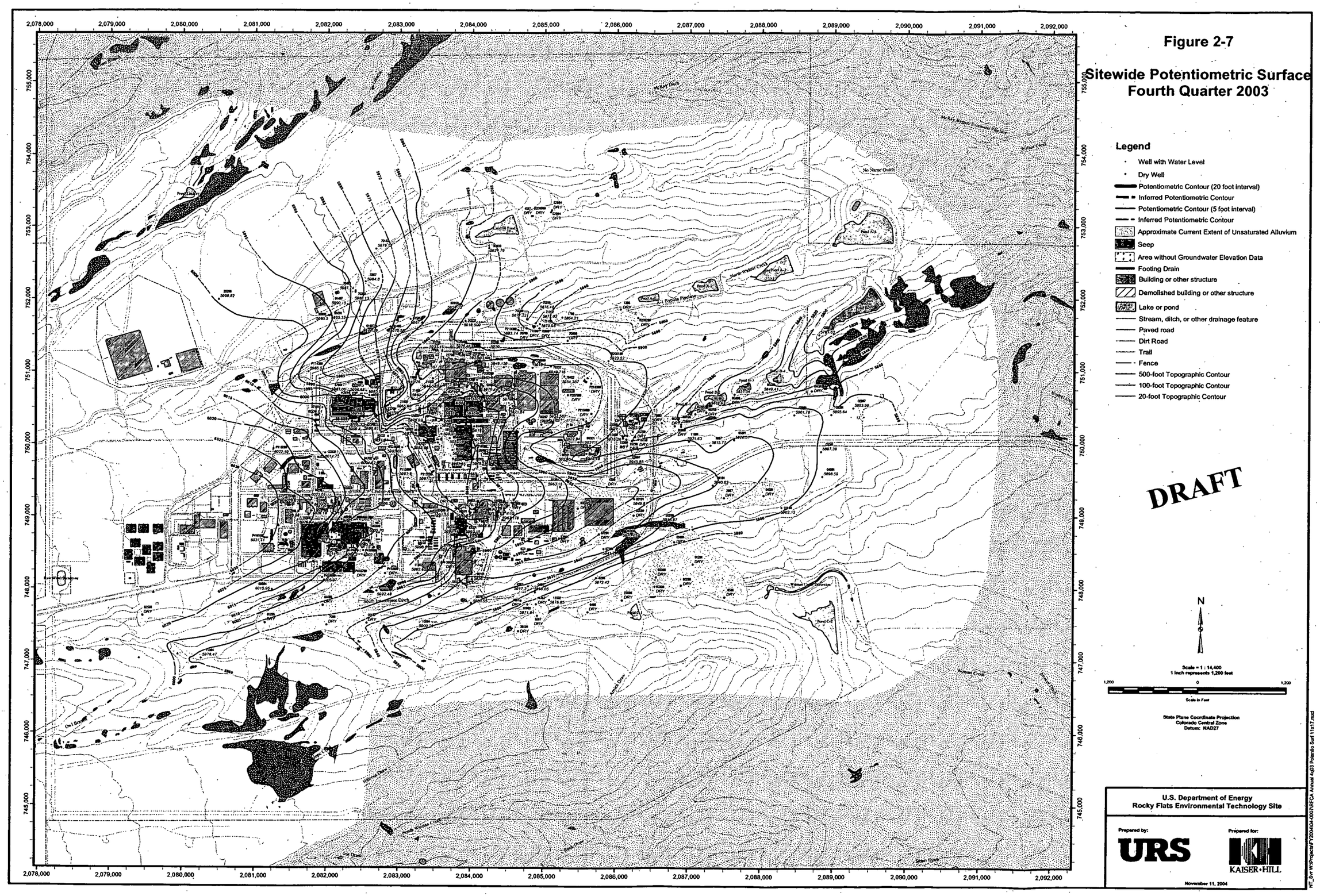
Figure 2-7
Sitewide Potentiometric Surface
Fourth Quarter 2003
Legend
Well with Water Level
Dry Well
Potentiometric Contour (20 foot interval)
Inferred Potentiometric Contour
Potentiometric Contour (5 foot interval)
Inferred Potentiometric Contour
Approximate Current Extent of Unsaturated Alluvium
Seep
Area without Groundwater Elevation Data
Footing Drain
Building or other structure
Demolished building or other structure
Lake or pond
Stream, ditch, or other drainage feature
Paved road
Dirt Road
Trail
Fence
500-foot Topographic Contour
100-foot Topographic Contour
20-foot Topographic Contour
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Scale = 1 : 14,400
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Pond A-2
Pond A-1
Pond B-5
Pond B-4
Pond B-3
Pond B-2
Pond B-1
Pond C-2
Pond C-1
South Interceptor Ditch
Walnut Creek
Woman Creek
Ow Brook
Rock Creek
Smith Gulch

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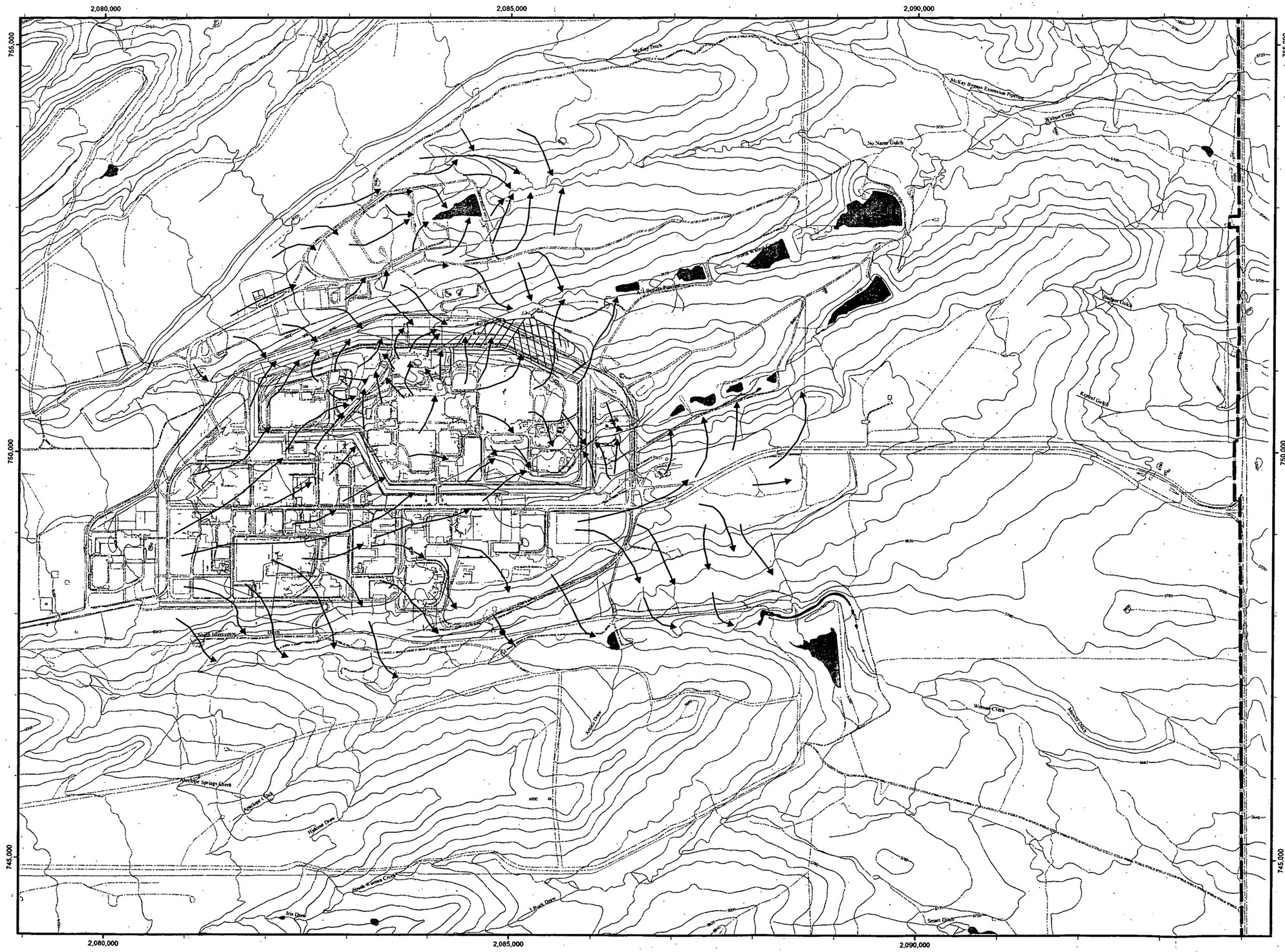

Figure 2-8
Groundwater Flow Paths - Future Site Configuration

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Legend

- Groundwater flow direction at closure

Standard Map Features

- Building or structure
- Groundwater treatment system
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Topographic contour (20 foot)

Note:
Length of arrow does not correspond to groundwater velocity.

N

Scale = 1 : 14,400
1 inch represents 1,200 feet

600 0 600 1,200
Scale in Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: URS

Prepared for: KH KAISER-HILL

November 30, 2004

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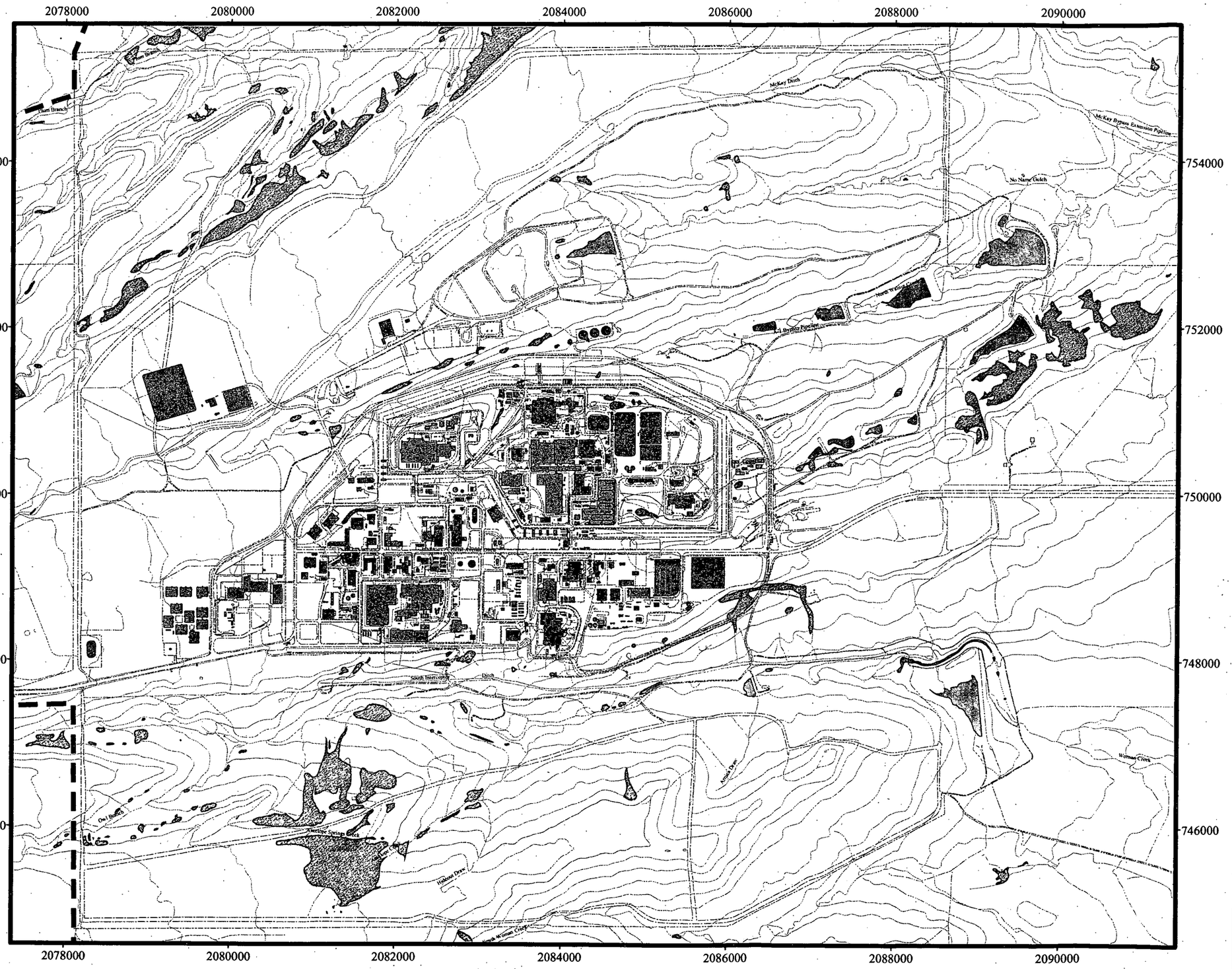

Figure 2-9
Seep Areas

Standard Map Features

- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Data Source:
Seep locations from EG&G, 1995, Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site.

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: November 30, 2004

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Prepared for:

KAISER•HILL

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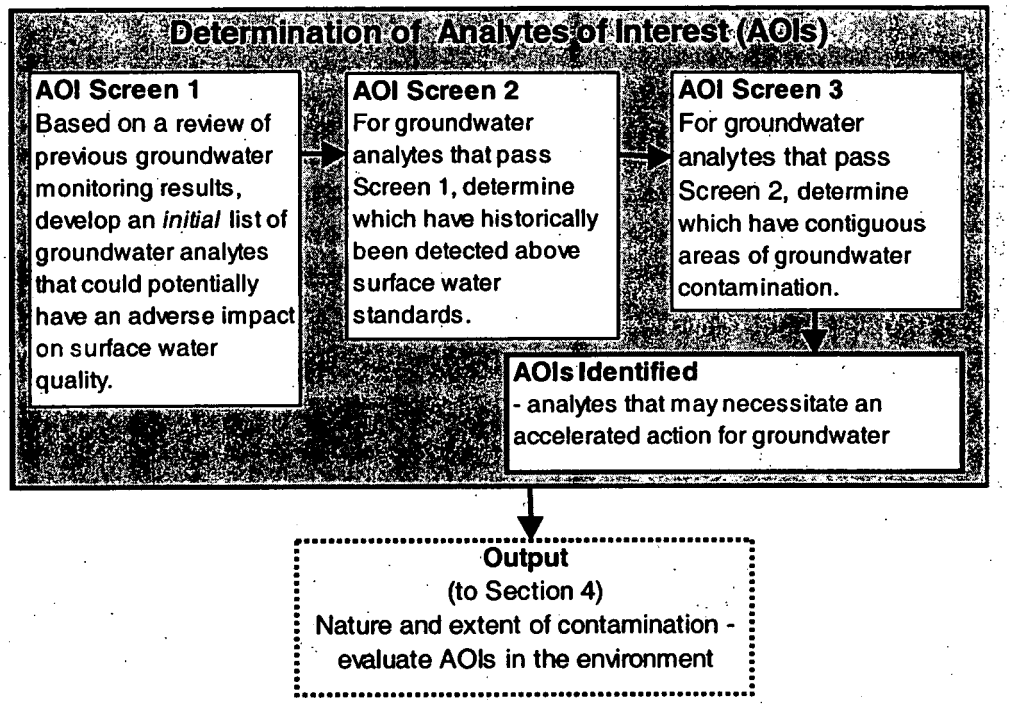
3.0 DETERMINATION OF ANALYTES OF INTEREST

3.1 Introduction

Groundwater AOIs for this IM/IRA were determined using three major screening steps, as depicted on Flow Chart 3-1.

Flow Chart 3-1. Process to Determine AOIs for the Groundwater IM/IRA



The three AOI screening steps shown on Flow Chart 3-1 are summarized briefly below. Detail on each of the three screening steps is provided in Sections 3.2, 3.3, and 3.4, respectively.

- AOI Identification Screen 1 - Review historical groundwater monitoring results – Perform a review of historical groundwater investigations to identify an initial list of analytes, or categories of analytes, that are assessed as being the most likely contaminants to adversely impact surface water quality. The initial list of analytes is based on their observed concentrations and/or extent of groundwater contamination. Analytes identified in this step are further evaluated in Screening Steps 2 and 3 to determine whether they warrant being included on the list of AOIs.
- AOI Identification Screen 2 – Compare groundwater data with surface water standards - Compare the analytes identified in the review of historical data (Screening

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Step 1) with the corresponding surface water standard for each respective analyte. Groundwater analytes that have never been detected above their corresponding surface water standard, at any well, are removed from consideration and are not evaluated further.

- AOI Identification, Screen 3 – Determine analytes with contiguous groundwater plumes - For each analyte that passes Screening Step 2 , plot the groundwater sample results on a map and determine whether a contiguous groundwater plume exists. If a contiguous plume *does not* exist, the analyte is not included on the list of AOIs. If a contiguous plume *does* exist, the analyte is included on the list of AOIs, as well as the evaluation presented in this report.

3.2 AOI Identification Screen 1 – Review Historical Groundwater Monitoring Results

The first step in determining the AOIs is to review historical groundwater monitoring results to determine analytes, or categories of analytes, that are the most likely to adversely impact surface water quality. This section presents a chronological history of the regulatory issues related to groundwater monitoring, and the groundwater monitoring activities that have occurred at the Site.

3.2.1 Regulatory History of Groundwater Monitoring at RFETS

Prior to 1981, the groundwater monitoring program at the Site was voluntary. Beginning in November 1981, the groundwater monitoring program became subject to RCRA regulations. Per regulatory requirements, DOE submitted a Groundwater Monitoring Program Plan (Rockwell International, 1981a) to the EPA in November 1981. This document addressed groundwater monitoring at the SEPs and in the vicinity of the A- and B-Ponds. The program outlined in this plan governed groundwater monitoring at the Site until November 1986.

The requirements of RCRA and CERCLA were implemented at the Site in 1986 as a result of the 1986 Compliance Agreement between DOE, the Colorado Department of Health (CDH, currently the CDPHE), and EPA. Adherence to the Compliance Agreement required implementing a comprehensive program of site characterizations, remedial investigations (RIs), feasibility studies (FSs), and remedial/corrective actions. These actions were part of the DOE Comprehensive Environmental Assessment and Response Program (CEARP) (DOE, 1986). In November 1986, a new groundwater monitoring plan was submitted by DOE as part of a RCRA Part B Permit Application. This plan represented a significant change in the groundwater monitoring program at the Site in terms of the number of locations monitored, monitoring frequency, and analyte suites. The 1986 monitoring program was updated via the Installation Generic Monitoring Plan (IGMP) and the Site-Specific Monitoring Plan (SSMP) under the DOE CEARP in February 1987.

The groundwater monitoring program was revised again in the fall of 1988. Changes to the monitoring program were implemented in response to July 1988 CDH comments

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regarding the RCRA groundwater monitoring program and the annual RCRA groundwater monitoring report submitted by DOE in the spring of 1988. The revised program was submitted in October 1988 as a portion of the RCRA Post-Closure Care Permit Application. DOE received a Compliance Order from CDH in June 1989 regarding deficiencies to the RCRA groundwater monitoring program. During the remainder of 1989 there were a series of correspondences between the regulatory agencies and DOE regarding violations, which resulted in the September 1989 Groundwater Assessment Plan. This plan and its subsequent 1990 Addendum governed groundwater monitoring at the Site through 1991.

In 1991, DOE, EPA, and CDPHE entered into the IAG (discussed in Section 1.3), which was superseded by RFCA (also discussed in Section 1.3) in 1996. RFCA is the current regulatory agreement that governs groundwater monitoring and accelerated actions at RFETS. The Integrated Monitoring Plan (IMP), which is required under RFCA to implement environmental media monitoring programs at the Site, serves as the current Groundwater Monitoring Plan for RFETS. The IMP outlines the monitoring goals for groundwater and describes the various components of the groundwater monitoring program. The IMP replaced the Groundwater Protection and Monitoring Program Plan (EG&E, 1993), and was originally published in May 1997. Since FY 2004, the IMP has been updated quarterly (as needed) and annually to reflect any changes to the monitoring programs.

Since the development of the IMP, there has been substantial input from the regulatory agencies, cities, and stakeholders. This consultative process has influenced the locations of new monitoring wells, associated sampling suites for new and existing monitoring wells, and overall design of the current monitoring network. Agency and community input has been obtained by DOE, and DOE strategies have been transmitted to the communities through quarterly data exchange and Water Working Group meetings. In addition, IMP meetings are frequently scheduled to address the evolving nature of the IMP as the Site moves toward closure. Attendees to these meetings generally consist of, but are not limited to, representatives of the City of Broomfield, City of Arvada, City of Westminster, City of Northglenn, City of Thornton, Rocky Flats Coalition of Local Governments (RFCLOG), Rocky Flats Citizens Advisory Board (RFCAB), CDPHE, EPA, DOE, and DOE contractors.

3.2.2 Chronology of Groundwater Monitoring at RFETS

Groundwater monitoring has been conducted at RFETS since the first groundwater monitoring wells were installed in the vicinity of the original SEPs in 1954. Additional wells were installed in 1960, 1966, and 1971. Until 1974, groundwater monitoring activities focused primarily on the detection of select radionuclides and major ions (e.g., nitrate and fluoride), and the measurement of pH (Boss, 1973). Additional wells were installed, and the groundwater monitoring program was expanded in 1974 in conjunction with DOE and U. S. Geological Survey (USGS) efforts to characterize the hydrology of the Site (Hurr, 1976). Groundwater monitoring results for the Site were first reported in the 1974 Annual Environmental Monitoring Report (Dow Chemical, 1975).

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Additional wells were installed in 1981 and 1982 as part of the first RCRA groundwater monitoring program. The groundwater monitoring program was expanded significantly in 1986 when DOE entered into a Compliance Agreement with the State followed by the Site being added to the National Priority List (NPL) by EPA in 1989. Groundwater monitoring after 1986 included hazardous and radiological constituents. These pre-RFCA groundwater monitoring results were reported in environmental and groundwater monitoring reports by Rockwell International (1976, 1978, 1980, 1981b, 1982, 1983, 1984, 1985, 1986, and 1989), and EG&G (1990, 1991b, 1992, 1993b, and 1994a).

As described above, the IAG governed groundwater monitoring at the Site from 1991 until 1996 when RFCA became effective, which set forth the IMP as the current Groundwater Monitoring Plan for RFETS. Table 3-1 presents a summary of well installation and monitoring activities at the Site to date. In the following discussion and Table 3-1, the term "wells" includes well points and piezometers, which are generally installed with the intent of measuring water levels only, but at various times may have been properly developed and utilized for the collection of groundwater samples.

Well completion details for most wells installed prior to 1986 are incomplete. That is the primary reason why all wells from those years have been abandoned. Any pre-1986 well information that was available was included in the Hydrogeologic Characterization of the Rocky Flats Plant (Hydro-Search, 1986). Although the pre-1986 wells provided information regarding groundwater occurrence, elevation, and quality, they did not necessarily meet the stringent requirements of RCRA and CERCLA.

It is important to note that in recent years, specific isolated areas of the Site where well coverage has been observed to be lacking have had additional wells added. These wells serve to fill data gaps where assumptions had previously been made as to the areal extent of specific contaminants. Also, in specific areas where certain analytes are known to be present, there have been additional or special samples collected that are not reflected in Table 3-1.

The groundwater investigations and extensive monitoring conducted at RFETS have shown that past Site operations have released hazardous and radionuclide contaminants to the UHSU. Contaminated soil at some of these sites has impacted shallow groundwater depending on the amount and duration of the release, subsurface soil hydraulic properties, net recharge, and physical and chemical characteristics of the individual constituents. The nature and extent of contaminants found in the UHSU have been determined from groundwater quality data collected for approximately 200 constituents at more than 1,200 wells installed at the Site.

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Table 3-1. Summary of RFETS Well Installations and Sampling Frequencies

Calendar Year	Approx. Number of Wells Installed	Rationale/Area Investigated	Laboratory Analyses	Sampling Frequency	Approx. Cumulative Number of Wells to Date[1]
1960[2]-1985	56	Mainly SEPs; also East Trenches, Woman Creek, B-Ponds, and 903 Pad; since 1976 Present Landfill area; since 1982 West Spray Field	Radionuclides only (Pu/Am, U-isotopes, and tritium) 1960 through 1984 (except for 1974 when fluoride, nitrate, TDS, and total alpha and beta were also analyzed); VOCs, phenols, trace metals, major cations and anions, TDS, TOC, and nitrate sampling began in 1985	Annually 1960-1973; Semi-annually 1974-1979; 3 times/year 1980-1981; Quarterly 1982-1985	56
1986	69	Provide more detailed characterization of Site hydrogeology and water quality	Metals (HSL plus Cesium, Molybdenum, and Strontium), Major Anions, VOCs (HSL), SVOCs (HSL), Pesticides/PCBs, Radionuclides (gross alpha and beta, U-isotopes, Pu/Am, and tritium)	Intended Quarterly; only 1 set collected during 1986 because new well construction not completed until 4th quarter	125
1987	68	Characterize SWMUs and RCRA regulated units	Same as 1986 except no SVOCs or pesticides/PCBs	Quarterly	193
1988	10	For water level measurements only; along utility lines	Same as 1986 except no SVOCs or pesticides/PCBs	Quarterly	203

(continued on next page)

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Table 3-1 (continued)

Calendar Year	Approx. Number of Wells Installed	Rationale/Area Investigated	Laboratory Analyses	Sampling Frequency	Approx. Cumulative Number of Wells to Date[1]
1989	162	Characterize upgradient and plant site groundwater quality and flow; also SEPs, Present Landfill, West Spray Field, OPWLs, East Trenches, 881 Hillside, 903 Pad	VOCs (TCL), metals (TAL), major anions, nitrate, radionuclides (gross alpha and beta, tritium, U-isotopes, Pu/Am, strontium, radium, and cesium), TDS, cyanide, DO, oil and grease	Quarterly	365
1990	18	North and south BZ (to site potential New Landfill); 881 Hillside investigation	Same as 1989 except no oil and grease	Quarterly	383
1991	87	Mainly Mound, East Trenches, 881 Hillside; also East BZ	Same as 1989 except no oil and grease	Quarterly	470
1992	30	881 Hillside, Woman Creek, and Walnut Creek	Same as 1989 except no oil and grease	Quarterly	500
1993	152	SEPs, Present Landfill, Woman Creek, and Walnut Creek	Same as 1989 except no oil and grease; DO discontinued during 1993	Quarterly	652
1994	85	West Spray Field, Present Landfill, Woman Creek IHSSs, and Indiana Street; also for water level measurements in dams and for Site gas station	Same as 1989 except no oil and grease, and no DO	Generally quarterly for most Site areas; information is vague	737

(continued on next page)

Table 3-1 (continued)

Calendar Year	Approx. Number of Wells Installed	Rationale/Area Investigated	Laboratory Analyses	Sampling Frequency	Approx. Cumulative Number of Wells to Date[1]
1995	180	Surface water seeps and SEPs; many for general Site potentiometric characterization	Same as 1989 except no oil and grease, and no DO	Generally Quarterly for RCRA wells; Semi-annually for other wells	917
1996	15	IA Characterization, New Landfill	Same as 1989 except no oil and grease, and no DO	Generally Quarterly for RCRA wells; Semi-annually for other wells	932
1997-2004	320	Characterization for areas adjacent to Mound, East Trenches, and Solar Ponds groundwater treatment systems and source removal accelerated actions; PU&D Yard, IHSS 118.1, IA Plume, 903 Pad/Ryan's Pit Plume, Oil Burn Pits #1 and #2, Original Landfill, Ash Pits, D&D Monitoring, and Actinide Migration Evaluation	With the implementation of the IMP, sampling became much more focused and dynamic based on project needs; main analytes included VOCs, nitrate, Pu/Am, uranium isotopes, metals, TDS, with special analyses if warranted based on process knowledge or special Data Quality Objectives (e.g., biodegradation indicators, major ions, SVOCs, cyanide, special radionuclides)	Quarterly for RCRA wells; Semi-annually for most other IMP wells	1,252[3]

Notes: [1] does not take into account wells that have been abandoned and is not indicative of the number of wells sampled each year; [2] there may have been 3 wells installed in 1954 in the area downgradient of the SEPs, the analytes and sampling frequency of these wells are unknown; [3] the total number of wells installed at RFETS varies with the sources researched; D&D = Decontaminate and Decommission; DO = dissolved oxygen; HSL = Hazardous Substance List; Mo = molybdenum; PCBs = polychlorinated biphenyls; SVOCs = semi-volatile organic compounds; TAL = target analyte list; TCL = Target Compound List; TDS = total dissolved solids; TOC = total organic carbon

Figure 3-1 displays the locations of all UHSU wells that have been sampled since 1991. Examination and interpretation of these data indicate that the most widespread UHSU groundwater contaminants, in terms of detectable plumes, include VOCs, nitrate, and uranium. The principal sources of VOC, nitrate, and uranium contamination have been

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identified through knowledge of Site processes, the HRR, numerous subsurface investigations, and past and current groundwater monitoring results.

Analysis of historic data indicates, among the many constituents evaluated, Pu, Am, metals, and tritium are not analytes considered to be AOIs. Although Pu and Am have been observed in surface soil and surface water at RFETS, these radionuclides are primarily transported as insoluble particulates by surface erosion processes, and not via groundwater (K-H 2002c). While historic monitoring wells at RFETS did, in some cases, contain varied concentrations of Pu and Am, it was determined that the origin of these actinides was not groundwater, but instead was primarily caused by surface soil with Pu and Am that contaminated the wells during their construction. To investigate this matter, four new wells were installed in 1999 at locations where Pu and Am concentrations in groundwater were historically highest. The new wells were constructed using a method specifically developed to minimize the amount of surface soil entering the borehole. These new, "aseptic" wells yielded groundwater analytical results that were orders of magnitude lower than the Tier II action levels (ALs) for Pu and Am (K-H, 2000a). These results support the understanding that groundwater at RFETS does not play a significant role in the transport of Pu or Am (K-H, 2002c).

A review of groundwater metals data indicates that metals at the Site do not form distinct contamination areas or plumes at concentrations that would drive accelerated actions per RFCA. Occurrences of high relative concentrations of metals observed at RFETS are typically isolated and are not associated with known contaminant plumes (K-H, 2004g). Many of the elevated metals concentrations at RFETS have been attributed to corrosion of stainless-steel well casing and screen, as well as downhole pumps (K-H, 2004g). These metals include nickel, chromium, and potentially thallium. Other metals detected at isolated locations, such as manganese and selenium, may be naturally occurring.

Tritium, while readily transported in groundwater, is rarely observed in groundwater at RFETS and observed concentrations are well below the groundwater ALs. Since 1995, there have been no activities of tritium measured in groundwater that are greater than the Tier II AL. In addition, with a half-life of 12.3 years, tritium would not be expected to persist in groundwater.

As noted in Section 1.3, the deeper groundwater in the LHSU is not evaluated in this IM/IRA. The upper Laramie Formation claystones of the LHSU, with low permeability, act as an effective aquitard that restricts downward vertical groundwater flow and associated downward migration of contaminants from the shallow groundwater in the UHSU to the LHSU and underlying Laramie-Fox Hills aquifer (Hurr, 1976; RMRS, 1996; K-H, 2004a).

3.2.3 Summary

In summary, groundwater monitoring activity at RFETS increased in intensity and focus during the 1980s and 1990s with regard to the number of wells sampled, number of constituents analyzed for, and areal extent of investigation. More than 1,200 wells have been installed at the Site since the early 1960s; many of these wells have been abandoned

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during the last five years as the Site moves toward closure. Since the implementation of the IMP, there has been routine regulatory agency and Stakeholder participation in the definition of the monitoring network, selection of well locations and analyte suites, and review of groundwater monitoring data.

Based on the findings of historic and current groundwater investigations, and the IMP process, one general analyte category and two specific analytes were identified in this AOI screening Step 1 that warrant further consideration for this IM/IRA: VOCs, nitrate, and uranium. While nitrate and uranium have areas of contiguous groundwater contamination at the Site, this is not the case for all of the 40 VOCs detected in groundwater. AOI Screening Steps 2 and 3 are described below to evaluate the VOCs, and include as AOIs only those VOCs detected above the surface water standard and in contiguous plumes.

3.3 AOI Identification Screen 2 – Compare Groundwater Data with Surface Water Standards

Groundwater sample data for those analytes that pass Screening Step 1 (VOCs, nitrate, and uranium) are then compared, in Screening Step 2, with surface water standards. This screening is conducted because the RAOs are based on the impact to surface water by contaminated groundwater. Therefore, if a specific analyte is measured in groundwater below its respective surface water standard, it meets all of the RAOs and is not considered further as a groundwater contaminant that could potentially require an accelerated remedial action. Results of this screening step are presented in Table 3-2.

The time frame for the analytical data set evaluated in this screen is from June 28, 1991 through August 31, 2004, consistent with the data set approved for the CRA methodology (K-H, 2004e). The June 28, 1991, start date corresponds to when the IAG Work Plan, and its data quality control (QC) measures, were first implemented. This initial screening is based on all acceptable (i.e., non-rejected) sample results for VOCs, nitrate, and uranium, for all wells, collected during this time frame.

3.4 AOI Identification Screen 3 – Determine Analytes With Contiguous Groundwater Plumes

Screening Step 3 involves determining which analytes have contiguous, mappable areas of groundwater contamination. The analysis is based on the most recent sample result for each well, to reflect the most recent groundwater conditions at the Site for the sampling time frame described in Section 3.3.

A specific analyte is removed from further consideration if the areal extent of the analyte, based on professional judgment, does not form a continuous, mappable area of contamination with a concentration above its respective surface water standard. For example, a contaminant detected above its surface water standard at a single well, or at several separate non-contiguous wells, does not constitute a continuous mappable contamination area. Results of AOI identification Screen 3 are presented in Table 3-2.

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Table 3-2. Summary of Detection and Screening Results to Identify Groundwater AOIs

AOI Screen 1					AOI Screen 2			AOI Screen 3		Final AOI List	Remarks
Analytes Selected for Analysis		Detection Results									
Chemical Class	Analyte (Identified In AOI Screen 1)	Number of Groundwater Sample Results	Number of Detections	% Detections	Number of Groundwater Samples Above Surface Water Standard	% of Samples Above Surface Water Standard	Screen 2 Result Considered for AOI List?	Detected In Contiguous Mappable Area Above Surface Water Standard?	Screen 3 Result Considered for AOI List?		
VOCs	1,1,1-TRICHLOROETHANE	7895	1170	14.8%	57	0.72%	Yes	No	No		
	1,1,2,2-TETRACHLOROETHANE	7889	28	0.4%	17	0.22%	Yes	No	No	-	
	1,1,2-TRICHLOROETHANE	7892	105	1.3%	32	0.41%	Yes	No	No	-	
	1,1-DICHLOROETHANE	7905	880	11.1%	0	0.00%	No	No (Screened out in Screen 2)		-	
	1,1-DICHLOROETHENE	7905	1374	17.4%	563	7.12%	Yes	Yes	Yes	1,1-DICHLOROETHENE	Several small isolated contamination areas
	1,2,4-TRICHLOROBENZENE	6486	92	1.4%	6	0.09%	Yes	No	No	-	
	1,2-DIBROMOETHANE	5876	10	0.2%	10	0.17%	Yes	No	No	-	
	1,2-DICHLOROBENZENE	6494	28	0.4%	0	0.00%	No	No (Screened out in Screen 2)		-	
	1,2-DICHLOROETHANE	7812	162	2.1%	75	0.96%	Yes	No	No	-	
	1,2-DICHLOROPROPANE	7895	91	1.2%	44	0.56%	Yes	No	No	-	
	1,3-DICHLOROBENZENE	6494	46	0.7%	0	0.00%	No	No (Screened out in Screen 2)		-	-
	1,4-DICHLOROBENZENE	6493	60	0.9%	9	0.14%	Yes	No	No	-	
	2-BUTANONE	2896	56	1.9%	0	0.00%	No	No (Screened out in Screen 2)		-	
	4-METHYL-2-PENTANONE	3692	22	0.6%	0	0.00%	No	No (Screened out in Screen 2)		-	
	ACETONE	3459	285	8.2%	2	0.06%	Yes	No	No	-	
	ACRYLONITRILE	61	0	0.0%	0	0.00%	No	No (Screened out in Screen 2)		-	
	BENZENE	7909	196	2.5%	68	0.86%	Yes	No	No	-	
	BROMODICHLOROMETHANE	7891	81	1.0%	38	0.48%	Yes	No	No	-	
	BROMOFORM	7833	19	0.2%	9	0.11%	Yes	No	No	-	
	BROMOMETHANE	7723	18	0.2%	4	0.05%	Yes	No	No	-	
	CARBON DISULFIDE	3727	82	2.2%	0	0.00%	No	No (Screened out in Screen 2)		-	
	CARBON TETRACHLORIDE	7938	2268	28.6%	1880	23.68%	Yes	Yes	Yes	CARBON TETRACHLORIDE	Large relative areal extent, multiple areas
	CHLOROBENZENE	7901	58	0.7%	2	0.03%	Yes	No	No	-	
	CHLOROETHANE	7848	83	1.1%	6	0.08%	Yes	No	No	-	
	CHLOROFORM	7891	2519	31.9%	1268	16.07%	Yes	Yes	Yes	CHLOROFORM	One extensive plume, several small areas
	CHLOROMETHANE	7833	52	0.7%	32	0.41%	Yes	No	No	-	
	cis-1,2-DICHLOROETHENE	5921	1815	30.7%	251	4.24%	Yes	Yes	Yes	cis-1,2-DICHLOROETHENE	Several small isolated areas
	DIBROMOCHLOROMETHANE	7894	12	0.2%	1	0.01%	Yes	No	No	-	
	ETHYLBENZENE	7898	86	1.1%	0	0.00%	No	No (Screened out in Screen 2)		-	
	HEXACHLOROBUTADIENE	6489	58	0.9%	4	0.06%	Yes	No	No	-	
	METHYLENE CHLORIDE	7847	1357	17.3%	422	5.38%	Yes	Yes	Yes	METHYLENE CHLORIDE	One isolated area
	NAPHTHALENE	6399	213	3.3%	21	0.33%	Yes	No	No	-	
	PROPANE, 1,2-DIBROMO-3-CHLORO-	3894	11	0.3%	11	0.28%	Yes	No	No	-	
	STYRENE	7885	25	0.3%	0	0.00%	No	No (Screened out in Screen 2)		-	
	TETRACHLOROETHENE	7960	3373	42.4%	2638	33.14%	Yes	Yes	Yes	TETRACHLOROETHENE	Large relative areal extent, multiple areas
	TOLUENE	7911	297	3.8%	1	0.01%	Yes	No	No	-	
	TOTAL XYLENES	6166	107	1.7%	0	0.00%	No	No (Screened out in Screen 2)		-	
	trans-1,2-DICHLOROETHENE	5941	151	2.5%	2	0.03%	Yes	No	No	-	
	TRICHLOROETHENE	7956	3442	43.3%	2433	30.58%	Yes	Yes	Yes	TRICHLOROETHENE	Large relative areal extent, multiple areas
	VINYL CHLORIDE	7874	252	3.2%	163	2.07%	Yes	Yes	Yes	VINYL CHLORIDE	Several small isolated areas
Major Ions	NITRATE/NITRITE	6061	5537	91.4%	888	14.65%	Yes	Yes	Yes	NITRATE/NITRITE	One extensive area at SEPs
Radionuclides	URANIUM (SUM OF ISOTOPES)	5794	5794	100.0%	1834	31.65%	Yes	Yes	Yes	URANIUM (SUM OF ISOTOPES)	One extensive area at SEPs; several small areas

The surface water standard is the criterion used in Screening Step 3 to delineate boundaries for mappable groundwater contamination areas, because the accelerated actions described in this IM/IRA are intended to address the impact of groundwater on surface water.

Maps of groundwater data at discrete well locations, for those analytes selected to be AOIs, are presented on Figure 3-2 through Figure 3-11. Maps of groundwater analytes reviewed for contiguous groundwater contamination areas, but not selected as AOIs, are included on a CD-ROM in Appendix A. On all of these figures, the results are separated into four categories, as shown below, to provide information relevant to the RAOs:

- Wells where an AOI is not detected;
- Wells where an AOI is detected but the reported concentration is less than the surface water AL, standard, or practical quantitation limit (PQL) in RFCA Attachment 5, ALF Table 1;
- Wells where an AOI concentration is greater than the surface water AL, standard, or PQL but less than or equal to the Surface Water Preliminary Remediation Goal (SWPRG); and
- Wells where an AOI concentration is greater than the SWPRG.

As summarized in Table 3-2, the final AOI list has 10 constituents, including eight VOCs, nitrate, and uranium. Uranium results are presented as total uranium, versus individual uranium isotopes, because only total uranium has a relevant surface water standard. In addition to the screening step results, Table 3-2 also provides statistics on the number of sample results for each contaminant, number of times each contaminant has been detected, and number of times each contaminant has been detected in groundwater above its corresponding surface water standard.

Previously published contaminant extent maps for the AOIs and other constituents can be found in many documents including previous Annual RFCA Groundwater Monitoring Reports (K-H, 1997a,1998a, 1999a, 2000a, 2001a, 2002b, and 2004a), Annual RCRA Groundwater Monitoring Reports (1987-1995), the Well Evaluation Report (EG&G, 1994b), individual Operable Unit RCRA Facility Investigation/Remedial Investigation (RFI/RI) reports, the Evaluation of Natural Attenuation and Biodegradation Potential of Chlorinated Aliphatic Hydrocarbon Compounds in Groundwater (K-H, 2004c), the Fate and Transport Modeling of VOCs at RFETS (K-H, 2004f), and the Actinide Migration Evaluation Pathway Analysis Report (K-H, 2002c).

3.5 AOIs and Regulatory Criteria

The three general categories of groundwater and surface water regulatory criteria, as discussed in Section 1.0, and their relevance to this IM/IRA, are discussed below:

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- Groundwater ALs (defined in RFCA ALF) – The Tier II AL is equivalent to the MCL for drinking water (or, for analytes without promulgated MCLs, based on values that are as protective as MCLs). A Tier I AL is equivalent to 100 times the MCL. Actions in response to a Tier I or Tier II AL reportable value in groundwater are presented in the IMP Background Document (K-H, 2003c).

- Surface water standards and ALs (defined in RFCA ALF) - Surface water standards and ALs are pertinent to this groundwater IM/IRA because the long-term remedial objective is for groundwater quality to be protective of surface water. Therefore, RAO 1 and RAO 3 for this IM/IRA are based on comparing groundwater quality with surface water standards and ALs. For most AOIs, the surface water standard is the same value, or the same order of magnitude, as the Tier II groundwater AL.

- SWPRGs – These remediation goals are the contaminant concentrations in surface estimated to cause a 1×10^{-6} increased risk of cancer, or have Hazard Index of 0.1, for the WRW, due to incidental ingestion of surface water while performing biological surveying tasks. The SWPRGs are defined in the CRA Work Plan and Methodology (K-H, 2004e). SWPRGs are related to this document because RAO 2 involves a comparison of groundwater quality with 10 times the SWPRG value (see RAO discussion in Section 1.6). For reference, the SWPRG for most AOIs is several orders of magnitude higher than the surface water standard.

As discussed in Section 1.4, the accelerated actions proposed in this document are intended to maximize early risk reduction at the Site and address areas of significant groundwater contamination, in a manner consistent with the RFCA objectives and ALF tiered approach. However, the evaluation process described in this IM/IRA focuses on RAOs, which are based on surface water standards and SWPRGs, and are anticipated to guide the final Site remedy for contaminated groundwater. Therefore, the accelerated actions proposed in this IM/IRA are intended to be consistent with both the near-term and long-term goals for remediation of RFETS groundwater.

For each AOI, Table 3-3 provides a listing of the groundwater ALs and relevant surface water regulatory criteria (i.e., surface water standards and SWPRGs) to provide a comparison of the regulatory criteria for the two media.

Table 3-3. Comparison of Groundwater and Surface Water Regulatory Criteria

AOI	Groundwater Regulatory Criteria		Surface Water Regulatory Criteria		
	Tier II Action Level	Tier I Action Level	Standard[1]	SWPRG	10 x SWPRG
1,1-Dichloroethene	7 µg/L	700 µg/L	7 µg/L	101,389 µg/L	1,013,890 µg/L

(continued on next page)

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Table 3-3 (continued)

AOI	Groundwater Regulatory Criteria		Surface Water Regulatory Criteria		
	Tier II Action Level	Tier I Action Level	Standard[1]	PRG	10 x PRG
Carbon Tetrachloride	5 µg/L	500 µg/L	5 µg/L (1 µg/L)	583.9 µg/L	5,839 µg/L
Chloroform	100 µg/L	10,000 µg/L	5.7 µg/L	20,278 µg/L	202,780 µg/L
cis-1,2-Dichloroethene	70 µg/L	7,000 µg/L	70 µg/L	18,250 µg/L	182,500 µg/L
Methylene Chloride	5 µg/L	500 µg/L	4.7 µg/L	10,121 µg/L	101,210 µg/L
Tetrachloroethene	5 µg/L	500 µg/L	5 µg/L (1 µg/L)	140.6 µg/L	1,406 µg/L
Trichloroethene	5 µg/L	500 µg/L	5 µg/L (2.7 µg/L)	189.8 µg/L	1,898 µg/L
Vinyl Chloride	2 µg/L	200 µg/L	2 µg/L	50.6 µg/L	506 µg/L
Nitrate	10 mg/L	1,000 mg/L	100 mg/L (10 mg/L)	3,244 mg/L	32,440 mg/L
Uranium	N/A	N/A	10 pCi/L	4,172.9 pCi/L	41,729 pCi/L

Note:

[1]The top value is the approved temporary modification to the surface water standard. The bottom value, in parentheses, is the surface water standard when the temporary modification expires.

3.6 Summary of the AOI Identification Process

In summary, based on a three-step screening process, AOIs were identified for further evaluation in this IM/IRA. The screening process takes into consideration: (1) historical groundwater monitoring data; (2) data that indicate a specific analyte has been detected in groundwater at concentrations above the surface water standard; and (3) data that indicate a specific analyte is present in contiguous, mappable areas.

Based on the screening process, 10 AOIs were identified, including eight VOCs (1,1-DCE, CT, CF, MC, cis-1,2-DCE, PCE, TCE, and VC), nitrate, and uranium. The AOIs are the groundwater contaminants identified as having the greatest potential to adversely impact surface water quality at RFETS.

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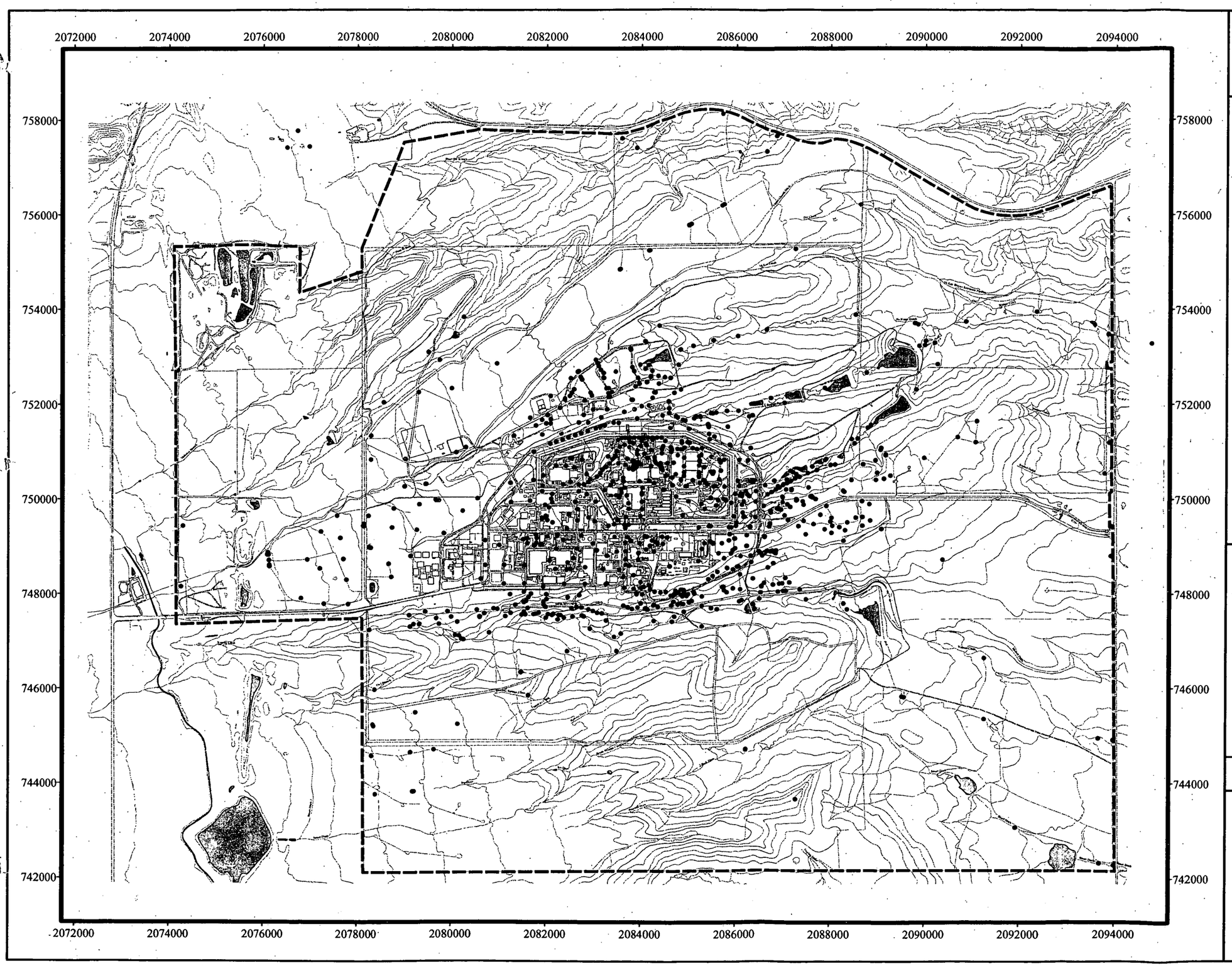

Figure 3-1
Location of UHSU Sample Wells

Legend

- Sample location

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Prepared by: Date: November 30, 2004

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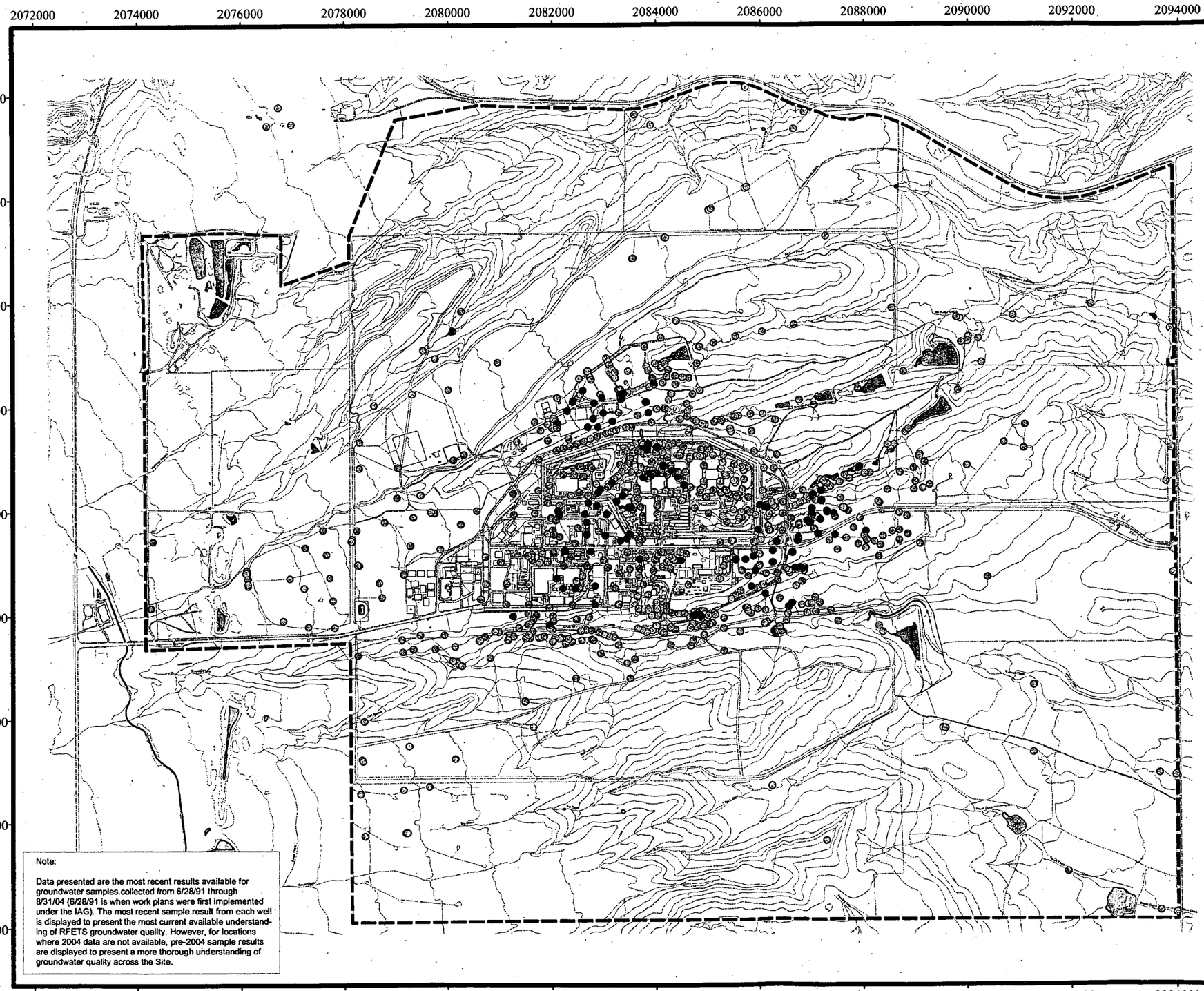
Figure 3-2
UHSU Groundwater, 1,1-Dichloroethene- Most Recent Sample Results



Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Legend

- Constituent concentration > 10 x SWPRG (1,013,890 ug/L)
- Constituent concentration > SWPRG (101,389 ug/L) and < or = 10 x SWPRG (1,013,890 ug/L)
- Constituent concentration > surface water standard (7 ug/L) and < or = SWPRG (101,389 ug/L)
- Constituent concentration < or = surface water standard (7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
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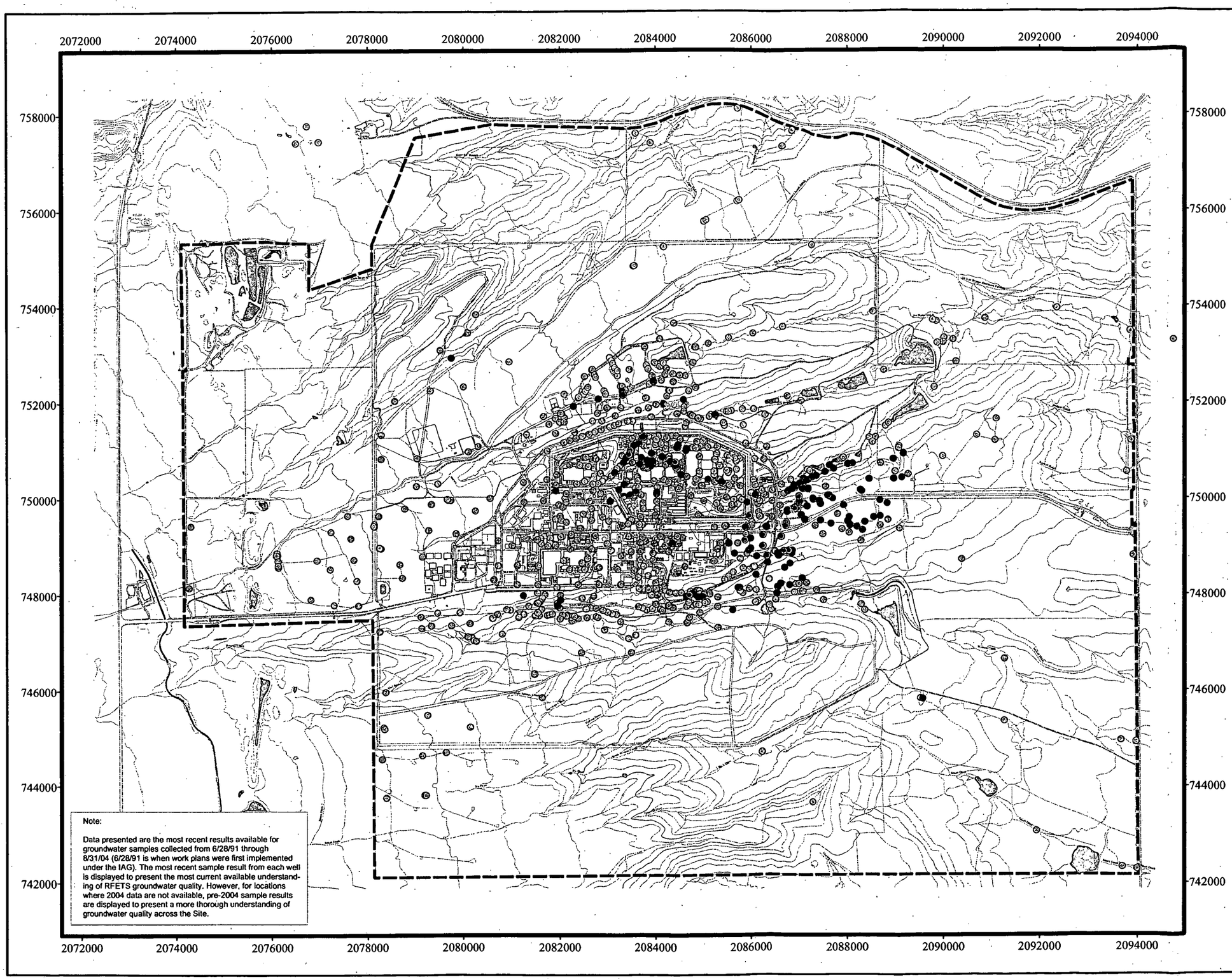

Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Figure 3-3
UHSU Groundwater, Carbon Tetrachloride - Most Recent Sample Results

Legend

- Constituent concentration > 10 x SWPRG (5,839 ug/L)
- Constituent concentration > SWPRG (583.9 ug/L) and < or = 10 x SWPRG (5,839 ug/L)
- Constituent concentration > PQL (1 ug/L) and < or = SWPRG (583.9 ug/L)
- Constituent concentration < or = PQL (1 ug/L)
- Constituent not detected

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
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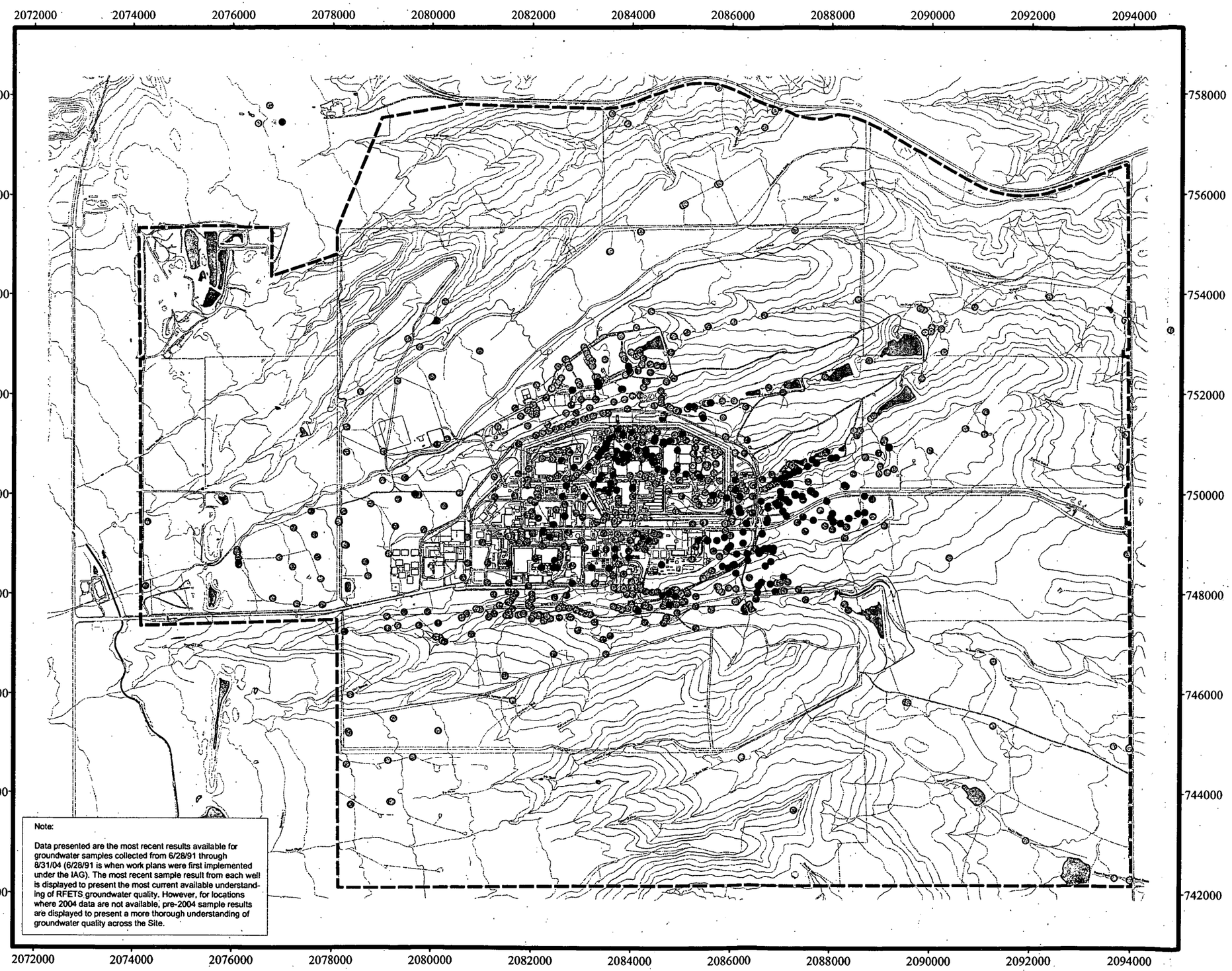

Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Figure 3-4
UHSU Groundwater, Chloroform - Most Recent Sample Results

Legend

- Constituent concentration > 10 x SWPRG (202,780 ug/L)
- Constituent concentration > SWPRG (20,278 ug/L) and < or = 10 x SWPRG (202,780 ug/L)
- Constituent concentration > surface water standard (5.7 ug/L) and < or = SWPRG (20,278 ug/L)
- Constituent concentration < or = surface water standard (5.7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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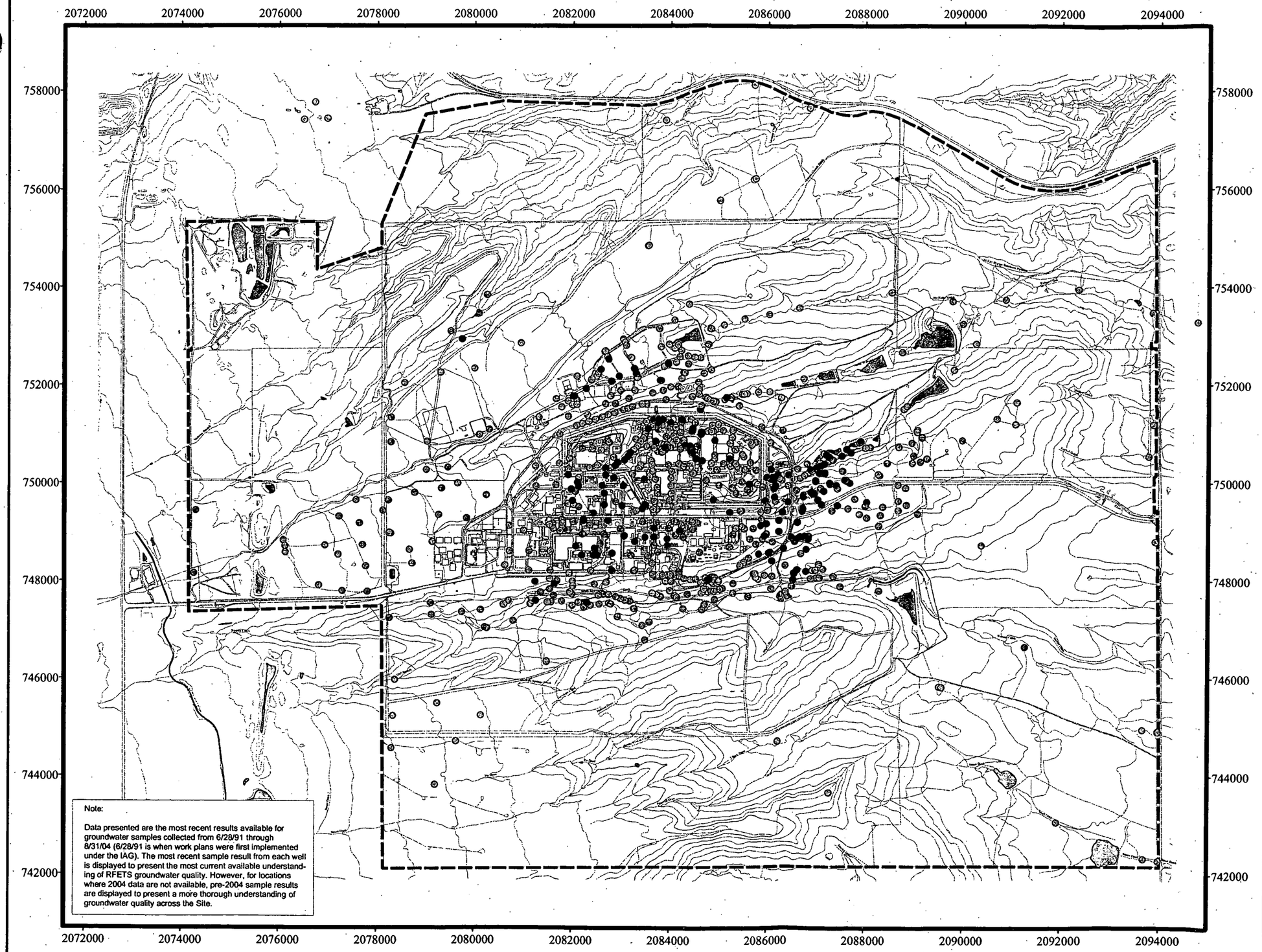

Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Figure 3-5
UHSU Groundwater, cis-1,2-Dichloroethene - Most Recent Sample Results

Legend

- Constituent concentration > 10 x SWPRG (182,500 ug/L)
- Constituent concentration > SWPRG (18,250 ug/L) and < or = 10 x SWPRG (182,500 ug/L)
- Constituent concentration > PQL (70 ug/L) and < or = SWPRG (18,250 ug/L)
- Constituent concentration < or = PQL (70 ug/L)
- Constituent not detected

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: December 7, 2004

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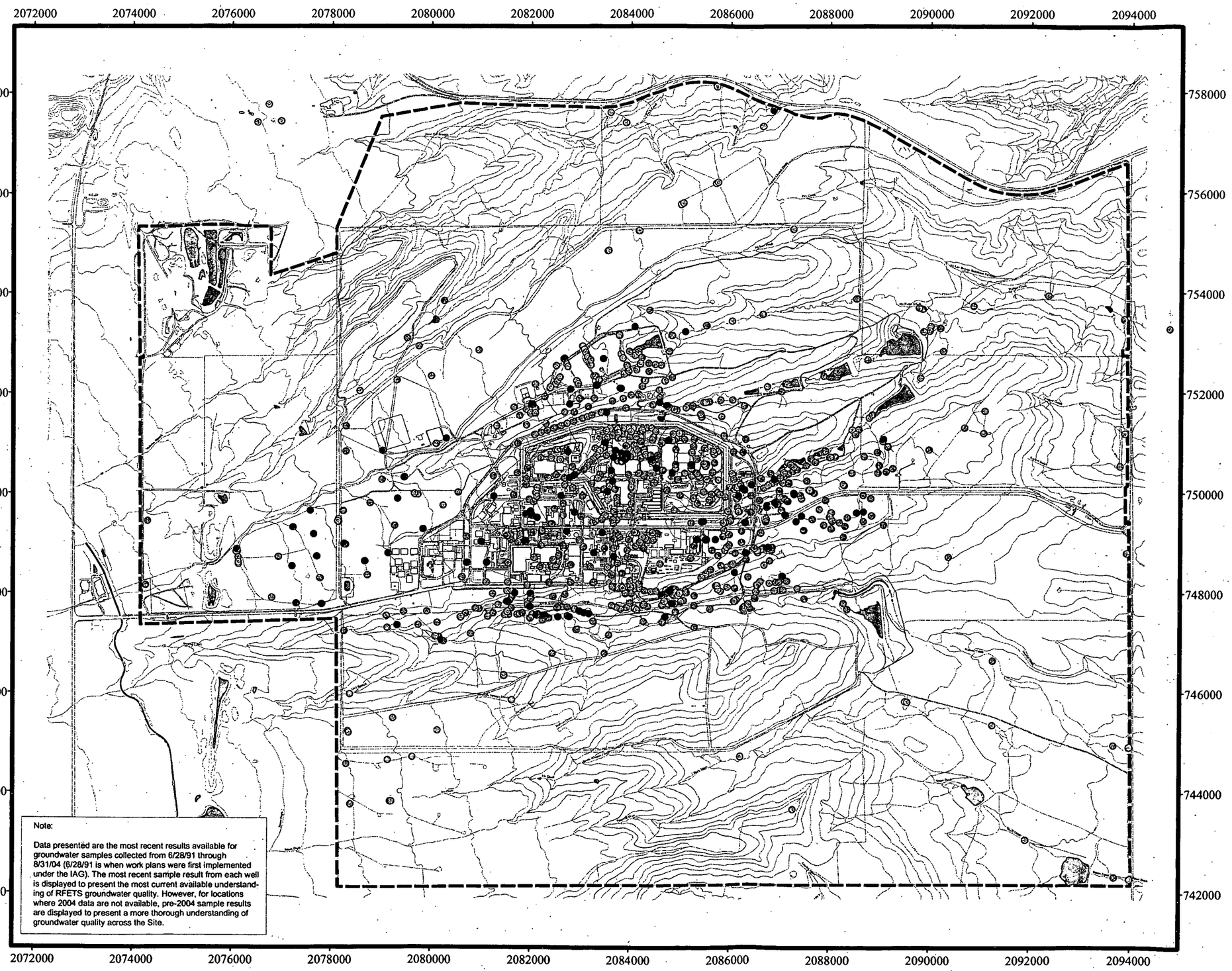
Figure 3-6
UHSU Groundwater, Methylene Chloride - Most Recent Sample Results



Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Legend

- Constituent concentration > 10 x SWPRG (101,210 ug/L)
- Constituent concentration > SWPRG (10,121 ug/L) and < or = 10 x SWPRG (101,210 ug/L)
- Constituent concentration > surface water standard (4.7 ug/L) and < or = SWPRG (10,121 ug/L)
- Constituent concentration < or = surface water standard (4.7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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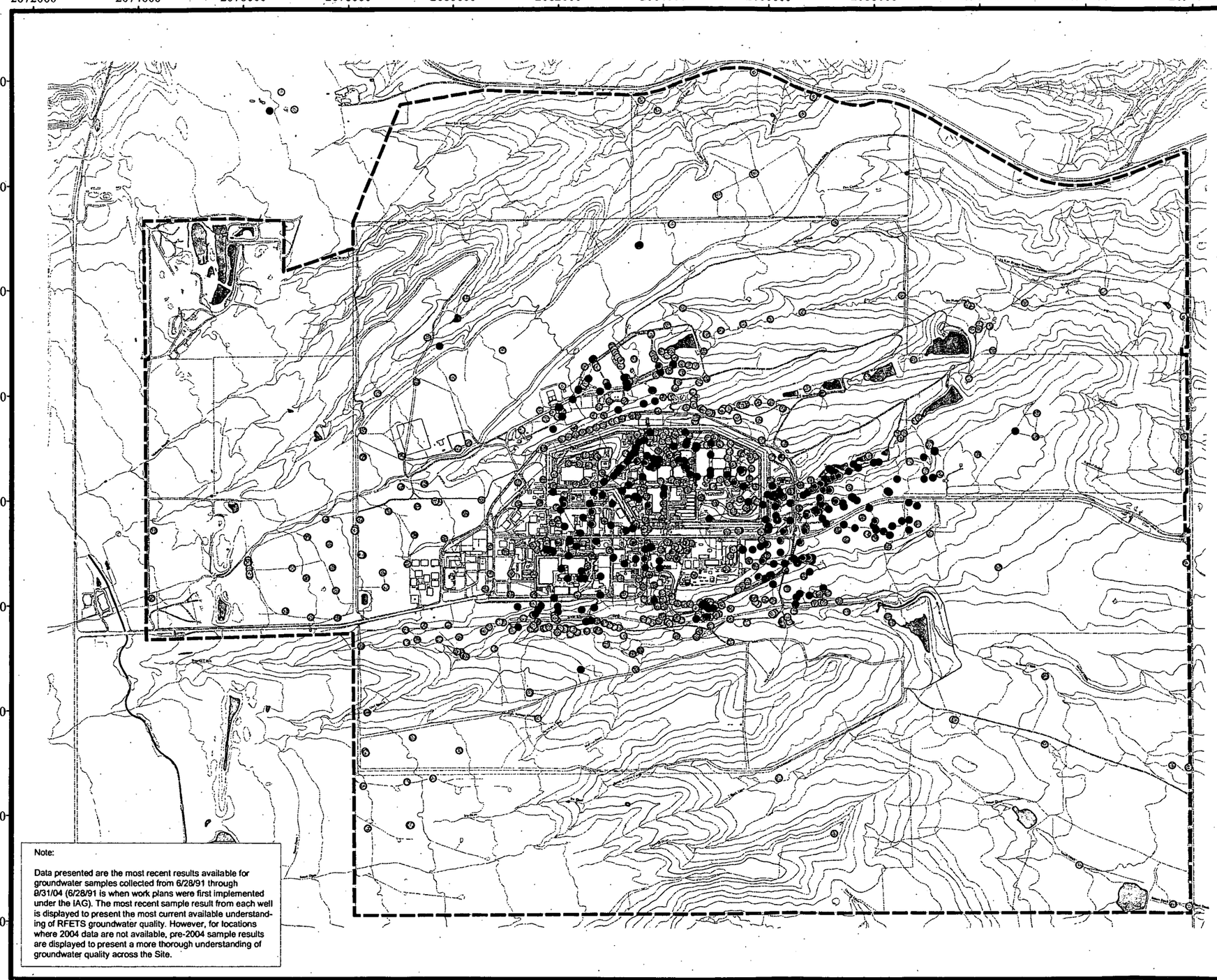
Figure 3-7
UHSU Groundwater, Tetrachloroethene - Most Recent Sample Results



Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Legend

- Constituent concentration > 10 x SWPRG (1,406 ug/L)
- Constituent concentration > SWPRG (140.6 ug/L) and < or = 10 x SWPRG (1,406 ug/L)
- Constituent concentration > PQL (1 ug/L) and < or = SWPRG (140.6 ug/L)
- Constituent concentration < or = PQL (1 ug/L)
- Constituent not detected

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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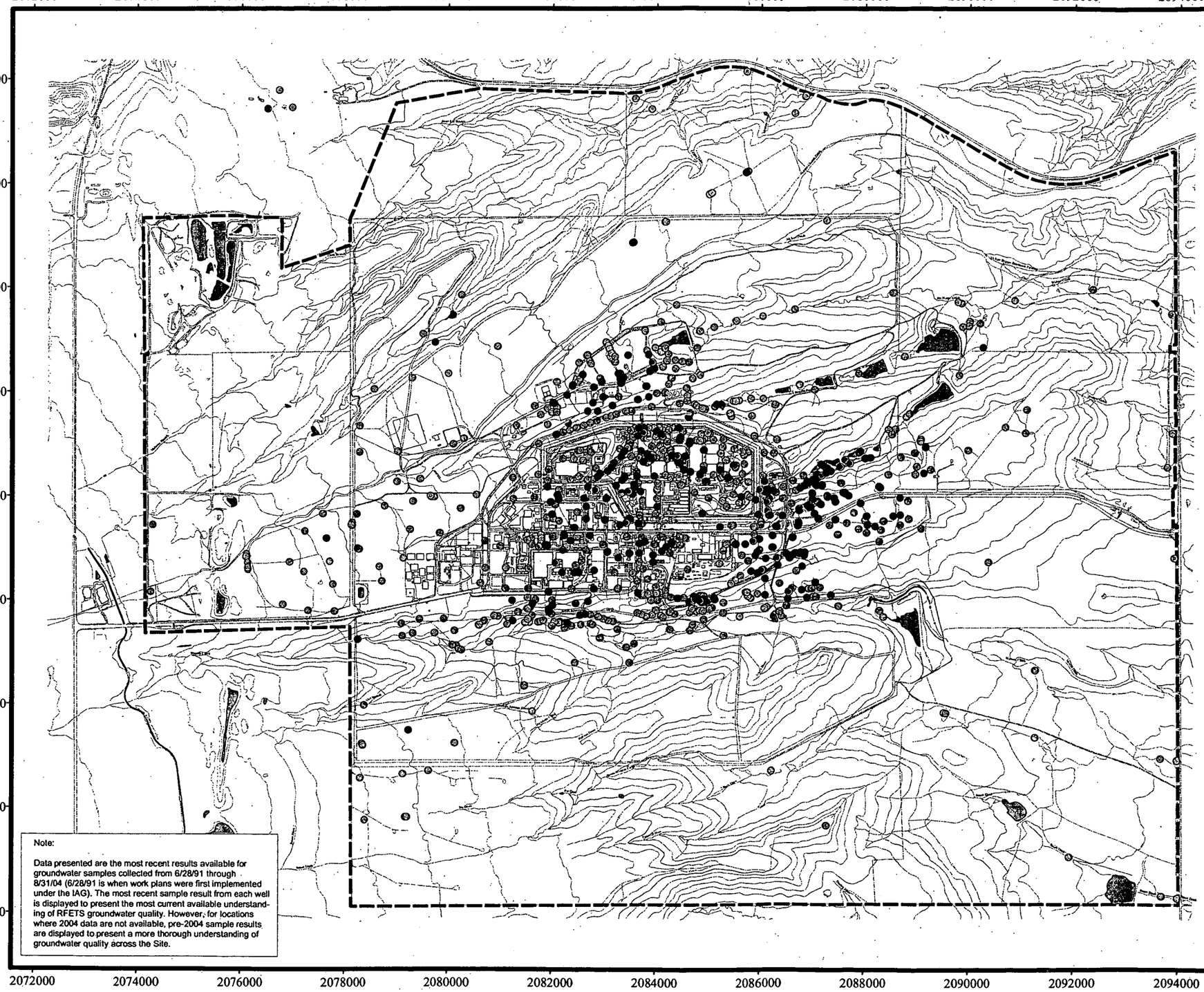

Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Figure 3-8
UHSU Groundwater, Trichloroethene - Most Recent Sample Results

Legend

- Constituent concentration > 10 x SWPRG (1,898 ug/L)
- Constituent concentration > SWPRG (189.8 ug/L) and < or = 10 x SWPRG (1,898 ug/L)
- Constituent concentration > surface water standard (2.7 ug/L) and < or = SWPRG (189.8 ug/L)
- Constituent concentration < or = surface water standard (2.7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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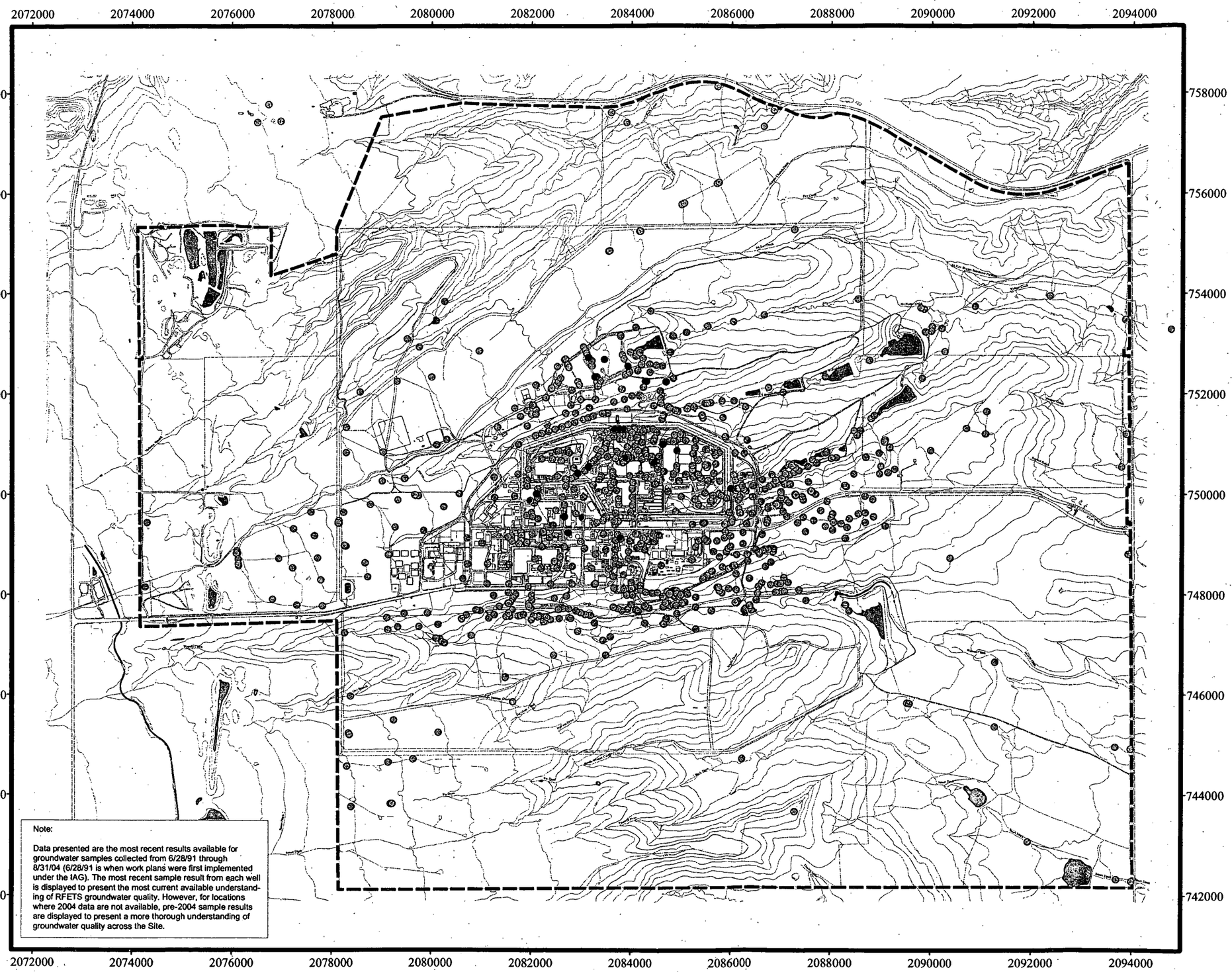
Figure 3-9
UHSU Groundwater, Vinyl Chloride - Most Recent Sample Results



Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Legend

- Constituent concentration > 10 x SWPRG (506 ug/L)
- Constituent concentration > SWPRG (50.6 ug/L) and < or = 10 x SWPRG (506 ug/L)
- Constituent concentration > surface water standard (2 ug/L) and < or = SWPRG (50.6 ug/L)
- Constituent concentration < or = surface water standard (2 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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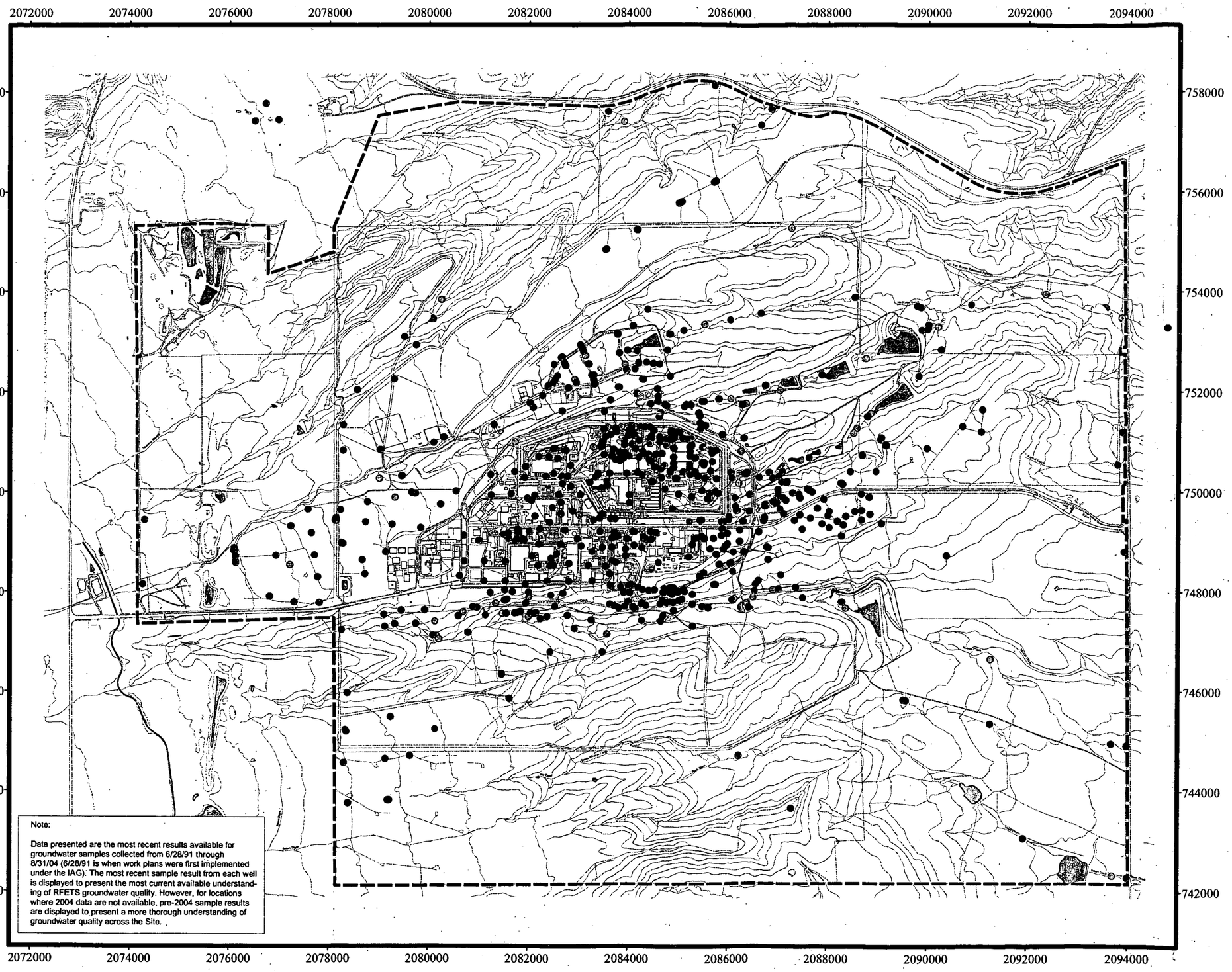
Figure 3-10
UHSU Groundwater, Nitrate/Nitrite (as N) - Most Recent Sample Results



Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Legend

- Constituent concentration > 10 x SWPRG (32,444 mg/L)
- Constituent concentration > SWPRG (3,244 mg/L) and < or = 10 x SWPRG (32,444 ug/L)
- Constituent concentration > surface water standard (10 mg/L) and < or = SWPRG (3,244 mg/L)
- Constituent concentration < or = surface water standard (10 mg/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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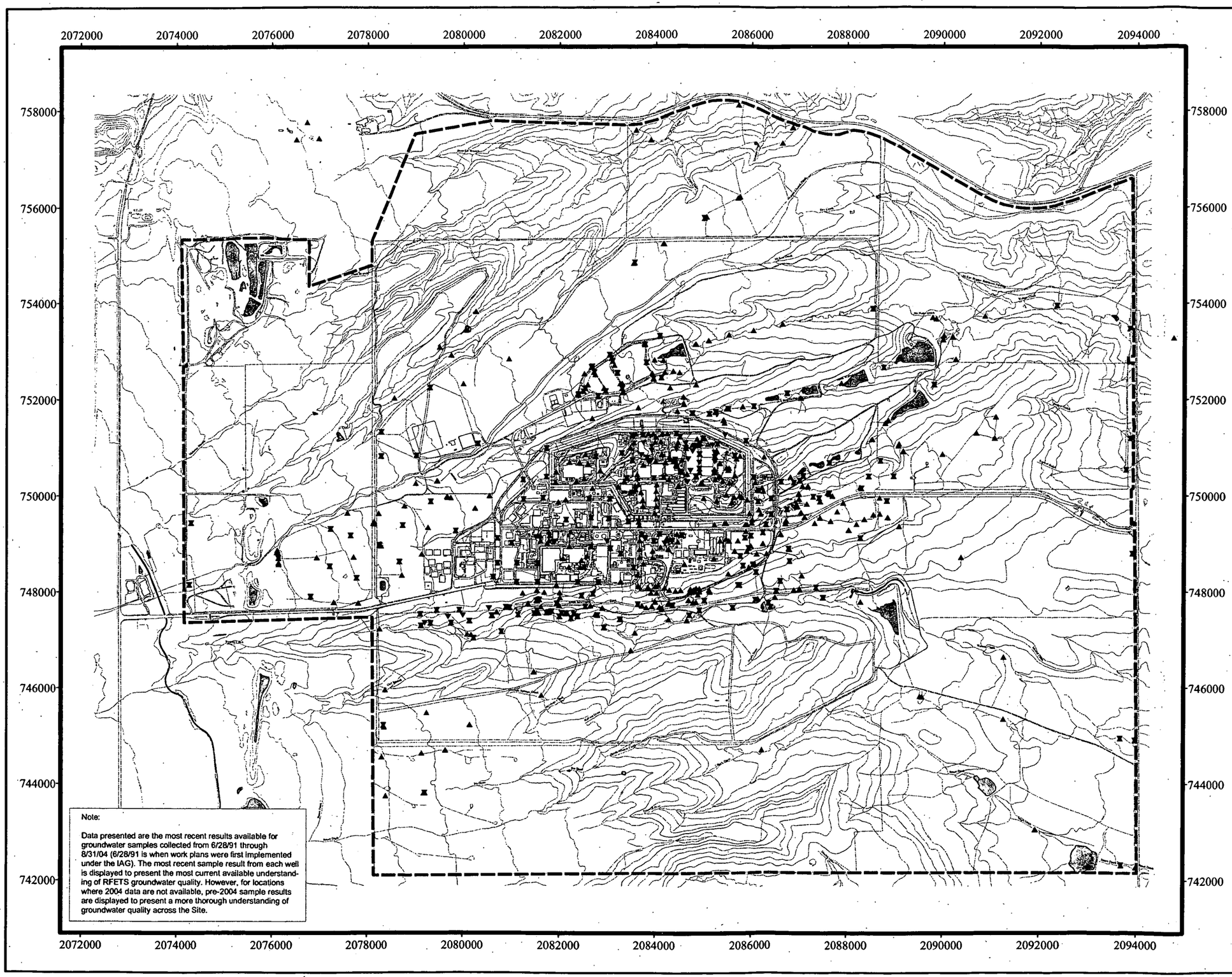
Figure 3-11
UHSU Groundwater, Total Isotopic Uranium - Most Recent Sample Results



Note:

Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

Legend

- Constituent concentration > 10 x SWPRG (41,729 pCi/L)
- Constituent concentration > SWPRG (4,172.9 pCi/L) and < or = 10 x SW PRG (41,729 pCi/L)
- Constituent concentration > surface water standard (10 pCi/L) and < or = SWPRG (4,172.9 pCi/L)
- Constituent concentration < or = surface water standard (10 pCi/L)
- Constituent not detected
- Filtered Uranium data
- Unfiltered Uranium data

Standard Map Features

- Existing or demolished building or structure
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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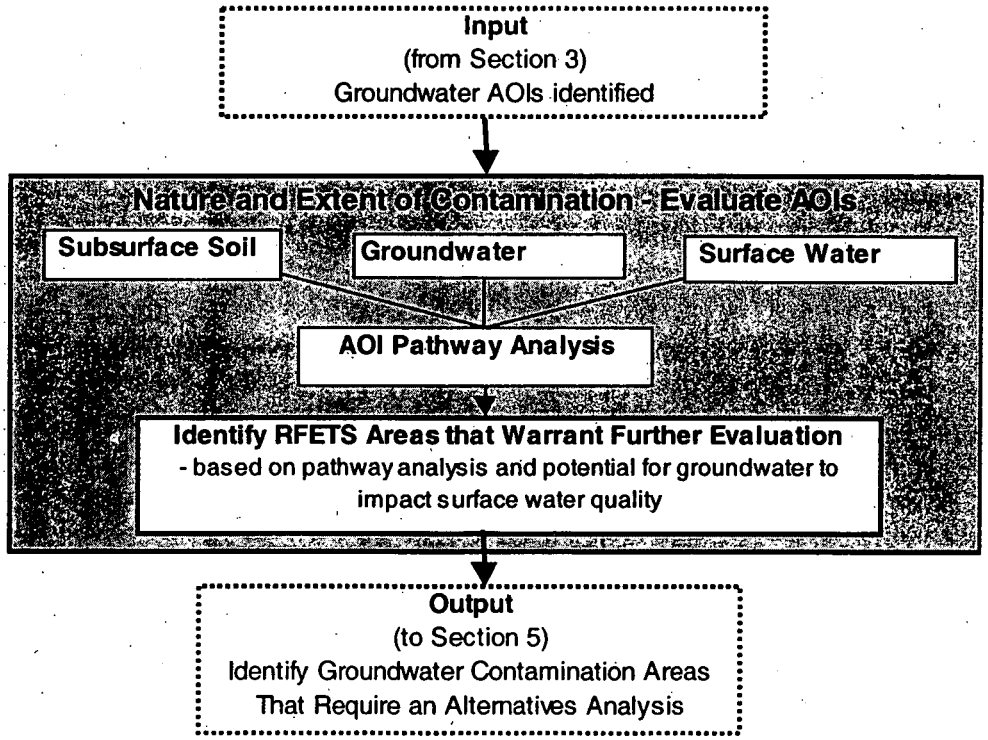
4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 Introduction

This section provides an evaluation of the nature and extent in the environment of the AOIs identified in Section 3.0. Environmental media addressed include subsurface soil, groundwater, and surface water. An assessment is made regarding the existence of a transport pathway to surface water for each AOI. Based on this assessment, groundwater contamination areas are identified that will require further analysis. That analysis is performed in Section 5.0. The evaluation process is diagrammed on Flow Chart 4-1.

Flow Chart 4-1. Nature and Extent of Contamination – Data Analysis Process



This section presents the current nature and extent of AOI contamination in subsurface soil, groundwater, and surface water. The purpose of reviewing data for environmental media other than groundwater was to determine where pathways exist for AOIs to be transported from subsurface soil to groundwater to surface water. Contaminants released to the environment generally migrate vertically into the unsaturated subsurface soil, or vadose zone, until they reach groundwater (the saturated zone), at which time they are able to migrate both laterally and potentially vertically based on physical and chemical

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properties of the contaminant and environmental media. Although the logical progression of contaminants from the surface is into subsurface soil, then groundwater, and finally into surface water, it is not uncommon to have a source of groundwater contamination that originates in the saturated zone. While subsurface soil contamination is not always responsible for groundwater contamination, the subsurface soil pathway is evaluated in this IM/IRA as a cross-reference to known groundwater plume areas.

A total of 15 general groundwater contaminant source areas at RFETS were identified for this IM/IRA, based on review of groundwater and subsurface soil data (see Figure 4-1). As stated earlier, groundwater in the Present Landfill (IHSS 114) and Original Landfill (IHSS 115) areas is not addressed in this Groundwater IM/IRA. Groundwater in those areas is addressed in the specific IM/IRAs for the Present Landfill (K-H, 2004b) and Original Landfill (IM/IRA pending approval). However, select figures in this document include the Present Landfill and Original Landfill for reference.

A general discussion of the transport and fate in the environment of VOCs, nitrate, and uranium is found in Section 4.2, followed by presentations of AOI data for subsurface soil (Section 4.3), groundwater (Section 4.4), and surface water (Section 4.5).

4.2 AOI Transport and Fate Characteristics

A discussion of the characteristics that affect the transport and fate of the AOIs is presented below. Detailed discussions of some of these characteristics are provided in K-H (2004b and 2004e) and Pankow and Cherry (1996).

4.2.1 Volatile Organic Compounds

VOCs are the most commonly occurring contaminants in groundwater at RFETS. Of the 10 AOIs identified, eight are VOCs. All of the RFETS groundwater VOC AOIs are chlorinated aliphatic hydrocarbons (CAHs), including chlorinated ethenes (PCE, TCE, cis-1,2-DCE, 1,1-DCE, and VC) and methanes (CT, CF, and MC). PCE, TCE, and CT were the primary chlorinated solvents used at the Site. Reductive dechlorination of PCE, TCE, and CT is the likely source of cis-1,2-DCE, 1,1-DCE, VC; CF, and MC as daughter products. However, some of the daughter products could also have existed as minor constituents in the industrial grade solvents used at the Site (K-H, 2004f).

The physical and chemical properties of CAHs govern their transport, fate, and toxicity in the subsurface environment. The number of substituted chlorine atoms on the CAHs directly affects their physical and chemical behavior. As the number of substituted chlorine atoms increases, molecular weight and density generally increase and vapor pressure and aqueous solubility generally decrease. Generally, as solubility decreases, sorption increases.

CAHs and petroleum hydrocarbons released to the subsurface as free-phase liquids are referred to as non-aqueous phase liquids (NAPLs) because of their generally limited solubility in water. Dense non-aqueous phase liquids (DNAPLs) are denser than water and, when released to the environment, tend to sink through both the vadose zone and saturated permeable soils until they reach the top of a confining layer or settle within a

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fracture. Capillary forces can trap DNAPLs in porous media above or below the water table.

CAHs in the subsurface can remain as a DNAPL, adsorb to soil, dissolve in groundwater, or volatilize to soil gas to the extent allowed by the physical and chemical properties of the individual CAH and the subsurface environment. Subsurface CAHs attempt to equilibrate with the subsurface environment via partitioning. Partition coefficients, which are related to the hydrophobicity and aqueous solubility of a CAH, define the extent to which a CAH will partition as NAPL, adsorb to soil, and dissolve in groundwater. The vapor pressure of a CAH defines the extent to which it will partition among NAPL, the soil, and soil gas.

CAHs dissolved in groundwater may also partition between dissolved and vapor phases as determined by their Henry's Law constant. However, once CAHs are dissolved in groundwater, their high volatility is of little assistance in their removal from the subsurface as transport across the capillary fringe can be exceedingly slow (McCarthy and Johnson, 1992). This process is distinct from attenuation via ET as described in Section 4.4.4.2. CAH volatility is very beneficial where groundwater discharges to flowing surface water and volatilization can occur.

CAHs migrate in the subsurface as non-aqueous, aqueous, and vapor phases by both active and passive processes. Active migration, such as advection and dispersion, transport CAHs along with groundwater or soil gas. Passive migration, such as diffusion, is the result of concentration gradients, which cause the CAHs to seek phase and concentration equilibrium with their surrounding environment. In groundwater, the transport effects of diffusion are negligible. The extent of subsurface migration is a function of the volume of CAH released, area and duration of the release, and physical and chemical properties of the CAH and the subsurface environment.

Infiltrating rainfall and seasonal water table fluctuations flowing through residual NAPL zones within the unsaturated zone may also provide a persistent source of CAHs into groundwater. Most of the current CAH distribution throughout the IA is caused by advection, where dissolved phase contaminants simply move in groundwater from source areas to downgradient areas. As a result, VOC contaminant distributions generally reflect groundwater flow directions, which, at RFETS, extend from pediment source areas to stream areas. Increased groundwater flow velocities in the unconsolidated material or Arapahoe No.1 Sandstone lenses within the weathered bedrock cause faster advective transport of CAHs relative to the weathered bedrock claystones. Although, as contaminants move from upper pediment areas downgradient towards stream areas (in the intervening hillslope areas), climate variability can cause groundwater levels to fluctuate across the weathered bedrock contact, which in turn causes increased mixing of the CAHs across the UHSU. This results in relatively small amounts of groundwater impacted by VOCs discharging into seeps, springs, or ponds.

CAHs can also be adsorbed onto the porous medium through which they travel. This causes decreased groundwater concentrations, although over time, adsorption rates may decline and thus this process may only retard the transport of higher concentrations from

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constant sources. Diffusive processes are typically small, at the scale of the VOC plumes. Their effects can become larger relative to dispersive effects in lower velocity areas, like weathered bedrock claystones.

The current extent of CAHs at RFETS is largely confined to groundwater in the IA and east-central BZ and surface water in the East Trenches area. This suggests that CAH transport is relatively slow in the UHSU and may have reached a steady-state condition. The apparently limited migration of CAHs in groundwater is likely a combination of several mechanisms, including UHSU hydraulic properties, climatic influences, Site underground infrastructure, source concentration, source flux, biodegradation, and sorption. These transport mechanisms and their relative importance are discussed in detail in Evaluation of Natural Attenuation and Biodegradation Potential of Chlorinated Aliphatic Hydrocarbon Compounds in Groundwater at Rocky Flats (K-H, 2004c) and Final Fate and Transport Modeling of Volatile Organic Compounds at Rocky Flats Environmental Technology Site (2004f).

4.2.2 Nitrate

Nitrate (NO_3^-) and nitrite (NO_2^-) are naturally occurring inorganic anions, which are part of the nitrogen cycle. Other common forms of dissolved nitrogen in groundwater may include ammonium (NH_4^+), ammonia (NH_3), nitrogen (N_2), nitrous oxide (N_2O), and organic nitrogen, depending on redox conditions. Nitrate contamination is typically associated with nitrogen-containing fertilizers, including anhydrous ammonia, animal or human natural organic wastes, atmospheric emissions, and disposed municipal and industrial wastes. The primary source of nitrate contamination at RFETS was the former SEPs, where low-level liquid radioactive wastes contaminated with high concentrations of nitrate were held for evaporation of water (DOE, 1992).

Naturally occurring nitrates in soil, surface water, and groundwater result from the decomposition by microorganisms of organic nitrogenous material such as the protein in plants, animals, and animal excreta. The ammonium ion formed is oxidized to nitrites and nitrates under aerobic conditions. Denitrification of nitrate and ammonia to nitrous oxide and elemental nitrogen can occur by bacterial action under anaerobic conditions (Fetter, 1980). The natural occurrence of nitrates and nitrites in the environment is a consequence of the nitrogen cycle. However, nitrites are short-lived in groundwater and generally only found in very low concentrations because most environments are oxic (i.e., well oxygenated), which favors the nitrate anion.

Because RFETS groundwater and surface water are generally oxic and nitrite is easily oxidized to nitrate, nitrate is the predominant dissolved nitrogen species in Site water. However, localized areas of other dissolved nitrogen species may occur where the groundwater is anoxic and reducing conditions exist.

Nitrate concentrations in groundwater are generally not limited by solubility constraints (Freeze and Cherry, 1979). As a result, nitrate in RFETS soil and groundwater is likely to be highly soluble and very mobile within the aqueous phase. From a transport perspective, nitrate is considered a conservative constituent, like chloride, because it is

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not readily sorbed (i.e., retarded) and generally migrates at the same rate as groundwater flow. However, in heavily vegetated areas, nitrate uptake by plants may influence its overall transport behavior (Drever, 1988).

4.2.3 Uranium

Uranium occurs naturally in the Earth's crust and is ubiquitous in the Front Range of Colorado (Langmuir, 1997). The presence of relatively large amounts of naturally-occurring uranium can complicate studies to identify uranium from anthropogenic (man-made) sources. High relative concentrations of uranium in the environment do not necessarily indicate an anthropogenic uranium source; high uranium concentrations in various environmental media at RFETS can frequently be attributed to natural sources.

Naturally occurring uranium contains isotopes U-234, U-235, and U-238 in essentially fixed percentages, regardless of the uranium concentration. Specific analytical methods, such as high resolution Inductively Coupled Plasma/Mass Spectrometry (ICP/MS), have been employed at RFETS to measure the uranium isotope masses and facilitate distinguishing between natural and anthropogenic uranium in groundwater (see Appendix B).

The oxidation state of an actinide, such as uranium, has a controlling effect on its environmental behavior. Actinides in the lower oxidation states (III and IV) tend to form complexes with very low solubilities that exhibit strong sorption to mineral and rock surfaces. In contrast, actinides in the higher oxidation states (V and VI) tend to form complexes with much higher solubilities that exhibit weaker sorption to mineral and rock surfaces. Uranium is most commonly found in the environment as U(IV) and U(VI) and, therefore, exhibits a range of environmental mobility. U(IV) tends to form strong hydrolytic complexes, form precipitates that are sparingly soluble, and adsorb strongly to mineral surfaces, thereby causing U(IV) to be largely immobile in groundwater. In contrast to U(IV), U(VI) is more soluble, undergoes weaker specific sorption, and tends to be more mobile in the environment (Salomons and Foerstner, 1984).

Uranium ions in aqueous solution can generate very complex species. Anions, such as carbonate, nitrate, chloride, fulvate, humate, and ethylenediaminetetraacetate (EDTA), form complexes with both U(IV) and U(VI), thereby increasing the amount of uranium that can remain in solution and, consequently, increasing the overall mobility of uranium. Uranium is generally least mobile in reducing (anaerobic) environments that are free of complexing anions and is most mobile in oxidizing (aerobic) environments that have high concentrations of complexing anions.

4.3 Subsurface Soil Contamination Pertinent to Groundwater

Subsurface soil characterization data, for the same analytes that were previously identified as the groundwater AOIs, are presented in this section to supplement and cross-reference the groundwater AOI data presented in Section 4.4. This section provides a summary of recent subsurface soil investigations, performed to characterize the current condition of the Site, and contains concentration maps of the 10 AOIs in subsurface soil

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(Figure 4-2 through Figure 4-11). If areas with elevated concentrations of AOIs in subsurface soil are consistent with the locations of existing groundwater plumes, then the subsurface soil data serve to confirm the groundwater data. If subsurface soil data indicate areas with high concentrations of the AOIs, and groundwater AOI data are not available for that area, then further evaluation of the groundwater in that area will be necessary to confirm that groundwater has not been significantly impacted.

4.3.1 Subsurface Soil Investigations

Subsurface soil characterization is performed, in many cases, as part of the ER evaluation for a specific area or IHSS group. Appendix C provides a summary of subsurface soil investigations that include the groundwater AOIs in the list of subsurface soil analytes.

4.3.2 Subsurface Soil Contaminant Data

For each of the 10 groundwater AOIs, maps were prepared for the same analytes in subsurface soil (Figure 4-2 through Figure 4-11). The purpose of the figures is to show the relative concentrations of the groundwater AOIs in subsurface soil. Data were queried from the Soil Water Database (SWD) for samples collected from June 28, 1991 through August 31, 2004, at depths greater than 6 inches below the ground surface. At locations where samples were collected at multiple depths, the maximum sample result for the location is displayed on the figure.

Locations are presented with designations for non-detect sample results, as well as sample results greater than 10 micrograms per kilogram (μg/Kg), greater than 100 μg/Kg, greater than 1,000 μg/Kg, and greater than 10,000 μg/Kg. The logarithmic scale concentration categories are utilized only to effectively display the wide range of subsurface soil concentrations at RFETS. The sample values on the figures are intentionally not categorized according to RFCA soil ALs, because the ALs are not necessarily indicative of the impact to groundwater, nor are they pertinent to a groundwater IM/IRA.

4.3.3 Summary of Subsurface Soil Contamination

Table 4-1 provides a summary of the subsurface soil sample results greater than 1,000 μg/Kg and 10,000 μg/Kg and the area of the Site where the samples were collected. Note that areas with high concentrations of AOIs in subsurface soil are frequently coincident with areas of relatively high concentrations of AOIs in groundwater (see groundwater spatial extent discussion in Section 4.4.2).

Table 4-1. Summary of Elevated Subsurface Soil Sample Results

AOI	Subsurface Soil Locations - Sample Results	
	Result > 1,000 μg/Kg	Result > 10,000 μg/Kg
Carbon Tetrachloride	East Trenches	IHSS 118.1, Oil Burn Pit #2
Chloroform	East Trenches, Building 443 area	IHSS 118.1

(Table continued on next page)

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Table 4-1 continued

AOI	Subsurface Soil Locations - Sample Results	
	Result > 1,000 µg/Kg	Result > 10,000 µg/Kg
Methylene Chloride	East Trenches, Oil Burn Pit #2, 903 Pad, Ryan's Pit, Building 443 area	IHSS 118.1
Tetrachloroethene	903 Pad, Ryan's Pit, PU&D Yard	IHSS 118.1, East Trenches, Mound Site, Oil Burn Pit #2, Building 991 (west side), Building 443, Oil Burn Pit #1
Trichloroethene	Mound Site, PU&D Yard, Building 443, Oil Burn Pit #1	Ryan's Pit, East Trenches, Oil Burn Pit #2
cis-1,2-Dichloroethene	903 Pad, Oil Burn Pit #1, East Trenches	None
1,1-Dichloroethene	None	None
Vinyl Chloride	None	None
AOI	**Result > 1,000 mg/Kg**	**Result > 10,000 mg/Kg**
Nitrate	SEPs	Downgradient from Present Landfill Pond
AOI	**Result > 100 pCi/g**	**Result > 1000 pCi/g**
Uranium	Ash Pits, 903 Pad, Ryan's Pit, Mound, East Trenches	Ash Pits

4.4 Groundwater Contamination

4.4.1 AOI Groundwater Source Areas

4.4.1.1 VOC Groundwater Source Areas

A total of 15 general groundwater contaminant source areas at RFETS were identified for this IM/IRA, based on review of groundwater and subsurface soil data (see Figure 4-1). Fourteen of these areas have identified VOCs, including nine primary VOC source areas. Based on information from the HRR, the VOC releases that resulted in these sources are estimated to have occurred 30 to 50 years ago. The nine primary VOC source areas generally correspond with major contaminant sources in the subsurface soil, and include the following:

- OU1 (IHSS 119.1);
- Mound Site (IHSS 113);
- Oil Burn Pit #2 (IHSS 153);
- 903 Pad (IHSS 112);
- Ryan's Pit (IHSS 109);

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- Carbon Tetrachloride Plume (IHSS 118.1);
- 700 Area Northeast Plume (no IHSS designation);
- East Trenches (IHSS Group 900-12); and
- Oil Burn Pit #1 (IHSS 128).

Five other VOC source areas with lesser concentrations and generally smaller relative areal extent (except for the IA Plume) in the soil and/or groundwater include:

- IA Plume (no IHSS designation; a combination of many localized areas of low-concentration VOC contamination in the central portion of the IA, originating from many small VOC sources and spanning the entire IA from north to south);
- Property Utilization and Disposal (PU&D) Yard (IHSS 170);
- Building 443 site (no IHSS designation; although NAPL was identified at the steam plant, a distinct groundwater plume has not been observed, probably due to the high viscosity of the NAPL);
- Building 991 (no IHSS designation); and
- Building 444 (no IHSS designation).

Accelerated actions to address several of the VOC source areas, and their impact on groundwater quality, have already been implemented. These remedial actions are discussed in Section 4.6.

4.4.1.2 Non-VOC Groundwater Source Areas

In addition to the VOC source areas, one specific source area does not have VOCs. Nitrate and uranium groundwater contamination exists in the vicinity of the former SEPs, which are the source of the Solar Ponds Plume (SPP) (K-H, 2004a). The nitrate and uranium contamination present in the SPP is migrating north to North Walnut Creek and south toward South Walnut Creek. The SPP Treatment System (SPPTS) was constructed to remediate impacts caused by the SPP (see Section 4.6). Note that TCE and PCE are also observed in the SEP area, although the source of these VOCs is to the west, where the 700 Area Northeast Plume originates.

Other locations have nitrate sources that are collocated with areas with VOC groundwater contamination. For example, low-concentration, nitrate-contaminated groundwater occurs locally at the 903 Pad and at 881 Hillside in former OU1.

4.4.2 Spatial Extent

Three-dimensional dispersion of VOCs can be defined as either a "plume," as defined in the Annual RFCA Groundwater Monitoring Reports, or as a plume signature area (PSA), as defined in the VOC transport modeling analysis (K-H, 2004f). Both of the terms,

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plume and PSA, are based on professional judgment and represent areas of groundwater contamination.

A plume is defined as a mappable, contiguous area of groundwater contamination. It shows an interpretation of the current areal extent of contamination and takes into account groundwater flow directions, but may present commingling of several groundwater sources. Plumes are not necessarily aligned with source areas, and do not represent a historical perspective.

A PSA represents the approximate, but distinct, source-plume areas with at least one source of contamination. The PSA shape, extent, and concentration distributions are developed using available groundwater flow paths, groundwater VOC concentrations, and HRR information. It represents the areal extent based on historical time-averaged concentrations. The PSA boundary concentration delineation is 10 μg/L.

The spatial extent of groundwater contamination was determined by developing interpretations of plume extent from the most recent analytical results at UHSU wells where groundwater quality samples were collected since June 28, 1991. The groundwater analytical data for each constituent were queried from the SWD for the period of June 28, 1991 through August 31, 2004. Groundwater concentration data vary temporally, but represent the last available results through the third quarter 2004 at each well. More than 85 percent of the data were collected in the past ten years.

Rejected data records from the SWD (based on validation or verification) were excluded from use in the preparation of maps for this IM/IRA. Also excluded were tentatively identified compounds (TICs), and all field- and lab-originated quality assurance (QA)/QC records. The data utilized appear to be representative of Site conditions and not spurious because the plumes depicted in this document are comparable to plumes identified in historic Site documents, as discussed in Section 3.2.2.

The spatial distribution of the 10 AOIs in groundwater is displayed on Figure 4-12 through Figure 4-21. The maps combine an interpretation of the plumes, based on well sampling results (discussed in Sections 4.4.2.1, 4.4.2.2, and 4.4.2.3), and the areal extent of the model-generated PSAs (for specific VOCs only; based on model results discussed in Section 4.4.4). The combination of empirical and model-based interpretations of the contamination extent provides a comparison of the different assessments for the extent of groundwater contamination at RFETS. In addition, for reference the figures display locations of groundwater contaminant source areas. As can be seen from the figures, neither representation significantly changes the areas of projected groundwater contamination in the UHSU.

4.4.2.1 Volatile Organic Compounds

Three VOCs, CT, PCE, and TCE, are the most widespread groundwater contaminants at the Site. Groundwater plumes containing these contaminants occur in the area of the East Trenches, 903 Pad/Ryan's Pit, Oil Burn Pit #2/Mound Site, IHSS 118.1, IHSS 119.1, and the 700 Area Northeast Plume. Descriptions are provided below for each of the VOC AOIs.

1,1-Dichloroethene

The most recent sample data for 1,1-DCE in UHSU groundwater at individual wells are shown on Figure 3-2. The spatial distribution of 1,1-DCE in UHSU groundwater is presented on Figure 4-12. The areal extent of mappable 1,1-DCE at the Site that is greater than or equal to the surface water standard is limited and confined to the central portion of the IA Plume, the former 903 Pad, the East Trenches, a small area immediately north of former Building 771, a small area at IHSS 119.1, and a few wells downgradient from the PU&D Yard.

Carbon Tetrachloride

The most recent sample data for CT in UHSU groundwater at individual wells are shown on Figure 3-3. The spatial distribution of CT in UHSU groundwater is presented on Figure 4-13. CT primarily occurs in the East Trenches Plume, 903 Pad/Ryan's Pit Plumes, IHSS 118.1, and the 700 Area Northeast Plume. Concentrations at numerous wells within these areas exceed the SWPRG. Numerous other wells have CT concentrations greater than the surface water standard or PQL but less than the SWPRG. These wells are also generally located with the predominant CT plumes discussed above. In addition, localized CT occurrences, often at one well, are found at Building 559, Building 707, IHSS 119.1, the Oil Burn Pit #2/Mound Site, the Modular Storage Tanks (MSTs), and the PU&D Yard. VOCs are detected in South Walnut Creek as a portion of the plume downgradient of the East Trenches Plume Treatment System continues to discharge to surface water.

Chloroform

The most recent sample data for CF in UHSU groundwater at individual wells are shown on Figure 3-4. The spatial distribution of CF in UHSU groundwater is presented on Figure 4-14. CF is most likely a result of the reductive dechlorination of CT. No well data exceed the SWPRG; however, a number of wells show concentrations greater than the surface water standard or PQL. The largest defined areas of CF contamination occur in IHSS 118.1, the East Trenches area, and 903 Pad/Ryan's Pit Plumes. The remaining CF occurrences are localized, generally occurring at only a few wells within known areas of VOC groundwater contamination, such as near the former SEP 207C (700 Area Northeast Plume), IHSS 119.1, Buildings 443/444 and 707, and former Buildings 865 and 662/663/666.

cis-1,2-Dichloroethene

The most recent sample data for cis-1,2-DCE in UHSU groundwater at individual wells are shown on Figure 3-5. The spatial distribution of cis-1,2-DCE in UHSU groundwater is presented on Figure 4-15. The areal extent of mappable cis-1,2-DCE at the Site that is greater than or equal to the surface water standard is very limited (less than 20 wells), and confined to Oil Burn Pit #1, a small portion the the IA Plume north-northeast of Building 444, and at and immediately downgradient of the former 903 Pad.

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Methylene Chloride

The most recent sample data for MC in UHSU groundwater at individual wells are shown on Figure 3-6. The spatial distribution of MC in UHSU groundwater is presented on Figure 4-16. Based on the most recent data, less than 20 wells at RFETS have MC concentrations greater than the surface water standard, and no MC concentrations exceed the SWPRG. MC concentrations greater than the surface water standard are limited in areal extent and do not form extensive contaminant plumes. The largest defined area of MC contamination occurs in IHSS 118.1, which is logical because MC is also a daughter product of the reductive dechlorination of CT. The remaining MC occurrences are localized, generally occurring at only one well within known areas of VOC groundwater contamination, such as the 903 Pad, IHSS 119.1, the PU&D Yard, and East Trenches area. It is noted that MC is a relatively common lab contaminant; therefore, it is often associated with "false positive" detections and MC data must be evaluated accordingly.

Tetrachloroethene

The most recent sample data for PCE in UHSU groundwater at individual wells are shown on Figure 3-7. The spatial distribution of PCE in UHSU groundwater is presented on Figure 4-15. PCE is the most spatially widespread contaminant of any of the VOCs found in groundwater at RFETS. Numerous wells within the PCE plumes show data that exceed the surface water standard. There are some wells, generally east of the IA, with PCE concentrations that exceed 10 times the SWPRG. The predominant PCE plumes occur in the East Trenches, 903 Pad/Ryan's Pit, the Oil Burn Pit #2/Mound Site, and IHSS 118.1. All of these plumes are associated with known VOC soil and groundwater sources. Smaller PCE plumes and localized occurrences are found in the area of the former SEPs, IHSS 119.1, the PU&D Yard, and throughout the IA. The spatial PCE distribution suggests that several sources likely contribute to these localized PCE occurrences.

Trichloroethene

The most recent sample data for TCE in UHSU groundwater at individual wells are shown on Figure 3-8. The spatial distribution of TCE in UHSU groundwater is presented on Figure 4-18. The distribution of TCE at RFETS is similar to, but not as extensive as, PCE. Although TCE was used at the Site as a solvent, some of the TCE in these plumes has probably resulted from the reductive dechlorination of PCE. Numerous wells within the TCE plumes exceed the surface water standard, and some wells, generally east of the IA, have TCE concentrations that exceed 10 times the SWPRG. The predominant TCE plumes occur in the East Trenches area, 903 Pad/Ryan's Pit, the Oil Burn Pit #2/Mound Site, and the PU&D Yard. Smaller TCE plumes and localized occurences, often just one well, are found in the area of the former SEPs, along the unnamed drainage between Buildings 371/374 and 771, IHSS 119.1, and at Building 991. The spatial TCE distribution suggests that several sources likely contribute to these localized TCE occurrences.

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Vinyl Chloride

The most recent sample data for VC in UHSU groundwater at individual wells are shown on Figure 3-9. The spatial distribution of VC in UHSU groundwater is presented on Figure 4-19. The distribution of VC is limited and occurs within known areas of VOC contamination. VC is not a primary contaminant at RFETS, but is a daughter product of the reductive dechlorination of PCE and TCE. Based on the most recent data, less than 20 well locations at RFETS exhibit VC concentrations greater than the surface water standard. Wells 33502 and 33604 are located in a small VC plume in the area of Oil Burn Pit #1 (IHSS 128). Both of these wells have VC concentrations greater than the SWPRG, and the concentration at well 33604 is greater than 10 times the SWPRG. Another well with a VC concentration greater than the SWPRG, well P115689, is located east of the former warehouse at Building 551 in IHSSs 117.2 (Middle Site Chemical Storage) and 169 (Waste Drum Peroxide Burial). The other, lower-concentration VC occurrences are localized, generally occurring within known areas of VOC contamination in the 400, 500, and 700 Areas, and the Mound Site.

4.4.2.2 Nitrate

The most recent sample data for nitrate in UHSU groundwater at individual wells are shown on Figure 3-10. The spatial distribution of nitrate in UHSU groundwater is presented on Figure 4-20. Based on the most recent data, numerous locations at RFETS exhibit nitrate concentrations greater than the surface water standard; only four of these locations (43693, 40993, 41593, and P209589) exhibit nitrate concentrations greater than the SWPRG (3,244 milligrams per liter [mg/L]). All of these locations are adjacent to the former SEPs within the SPP. The SPP is a large area of nitrate and uranium contamination that resulted from the leakage of liquid waste from the former SEPs. There are no locations at RFETS with nitrate concentrations that are 10 times the SWPRG.

Two small areas with nitrate contamination plumes are observed at the 903 Pad (IHSS 112) and OU1 (IHSS 119). These plumes are limited in areal extent. Additional scattered, localized occurrences (often one well) of nitrate in groundwater, at concentrations greater than the surface water standard but less than the human health SWPRG, are also presented on Figure 4-20.

4.4.2.3 Uranium

The most recent sample data for uranium in UHSU groundwater at individual wells are shown on Figure 3-11. The areal extent of uranium in UHSU groundwater is presented on Figure 4-21. The areal extent of uranium at the Site is widespread at activities greater than the surface water standard but less than the SWPRG. There are no locations at RFETS where the uranium activity is greater than 10 times the SWPRG. The largest area of contiguous uranium activity greater than the surface water standard has a source at the former SEPs and extends to the northeast to the North Walnut Creek drainage.

Other areas with uranium activity in groundwater, at concentrations higher than the surface water standard, are found on the hillside north of North Walnut Creek, near

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Building 991, the 881 Hillside, the IA from the north side of former Building 881 to Building 707, and the 903 Pad/Ryan's Pit area. However, as noted in Section 4.2.3, uranium occurs naturally and is therefore ubiquitous in groundwater. The presence of relatively large amounts of naturally occurring uranium can complicate studies to identify uranium from anthropogenic (man-made) sources. High Resolution ICP/MS analyses were employed to measure the uranium isotope masses and facilitate distinguishing between natural and anthropogenic uranium in groundwater (see Appendix B). Based on the ICP/MS analyses, the one area at RFETS with a definitive contiguous, mappable area of anthropogenic uranium is at the SEPs. Other areas of the Site with anthropogenic uranium appear to be in noncontiguous areas.

4.4.3 Summary of Measured Groundwater Contamination

Of the 10 AOIs identified in Section 3.0 of this document, the most widespread at concentrations greater than their respective surface water standards are CT, CF, PCE, TCE, nitrate, and uranium. 1,1-DCE has a moderate areal extent at concentrations greater than the surface water standard, and VC, MC, and cis-1,2-DCE have limited areal extents at concentrations greater than their respective surface water standards. Only four AOIs, CT, PCE, TCE, and VC have been detected at concentrations greater than 10 times their respective SWPRGs.

4.4.4 Modeled Future Conditions of VOCs in Groundwater

Integrated hydrologic and fate and VOC transport modeling was conducted for the IA and east-central BZ (K-H, 2004f). The objective of the modeling was to prepare a tool to predict the following:

- UHSU saturated zone fate and transport of VOCs from assumed source locations at assumed concentrations;
- Approximate surface discharge areas impacted by VOCs in support of the CRA; and
- Range of maximum groundwater concentrations at surface discharge locations for CT and PCE and their degradation products after buildings have been removed to 3 feet below grade and the Site has been regraded in accordance with the proposed land reconfiguration.

The modeling scope included: (1) collection, synthesis, and review of all historical VOC data available in SWD, (2) development of a flow and transport model of historic conditions to determine appropriate parameter values, and (3) development of a flow and transport model to predict long-term (or probable maximum) groundwater VOC concentrations that could discharge to surface water for a proposed land reconfiguration.

In addition, four local-scale integrated flow models were developed for the areas around building basements that will remain, below the ground surface, after Site remediation is complete. These local-scale models include the Building 771/774 area, Building 371 area, Building 881/883 area, and Building 991 area (including Building 991; the 996,

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997, and 998 Vaults; and the 991 and 998 tunnels). This local-scale modeling had two primary objectives: 1) determine the specific hydraulic concerns associated with leaving portions of the building in place, and 2) assess contaminant transport, if applicable. The local-scale integrated flow modeling conducted to support decommissioning activities is documented in Appendix D.

Simulation of VOC fate and transport within the unsaturated zone or streams was not considered. Surface water impacts from groundwater VOCs were not modeled or assessed. The scope did not include the simulation of the fate of any contaminants other than VOCs. Rather than simulating the fate and transport of total VOCs in groundwater, individual VOCs were modeled because differences in their chemical properties cause them to migrate at different rates. Finally, this study did not evaluate the performance of the groundwater collection and treatment systems installed for the Mound, East Trenches, and SEPs plumes.

4.4.4.1 Integrated Hydrologic Model Approach

Primary VOCs considered in this study were PCE, CT, and their daughter products. Successive daughter products of PCE include TCE, cis-1,2-DCE, and VC. Successive daughter products of CT include CF and MC. The occurrence of both parent and daughter product VOCs within most PSAs suggest biodegradation occurs at RFETS, although a separate Site study (K-H, 2004c) suggests rates are variable but typically very low throughout the model area. Additional evidence suggests that TCE occurs as a source in several areas, although, as mentioned previously, it is also a degradation product of PCE (K-H, 2004f).

A total of 19 VOC-impacted PSAs were identified where at least one source location explained a group of associated VOC-impacted sampling locations. PSAs represent approximate, but distinct, source-plume areas. As such, PSA delineations are uncertain due to well coverage, uncertainties in VOC source information, and the complexity of groundwater flow pathways.

Draft SWPRGs were used as the basis for determining whether individual PSAs would be modeled. The total number of PSAs modeled was reduced to 9 for PCE, 10 for TCE, and 7 for CT.

Reactive transport models were developed to simulate the fate and transport of VOCs in groundwater. A conceptual representation of VOC transport in the RFETS groundwater is shown on Figure 4-22. Effective source area concentrations, source depths, source locations, and key transport parameters were identified. In addition, ranges of values for key model input parameters (that adequately reproduce observed concentration distributions) were estimated for each plume area. The RT3D code, developed by the Pacific Northwest National Laboratory, was used to model the reactive transport of observed VOC degradation chains, along with other attenuation processes including sorption, diffusion, dispersion, and ET.

Proposed closure configuration simulation results from the integrated flow model were used as the basis for simulations using the GMS MODFLOW and RT3D codes. Long-

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term VOC fate and transport simulations for various closure configuration runs were conducted. A range of long-term, maximum groundwater VOC concentrations at groundwater discharge areas are estimated. The concentration ranges reflect uncertainty (conducted in sensitivity analyses) in key flow and transport model input parameter values. Results of multiple runs were compared against currently proposed SWPRGs. The general approach used to model VOC transport in groundwater at RFETS is diagrammed on Figure 4-23 (K-H, 2004f).

4.4.4.2 Model Results

Modeling results for FY03 conditions and a proposed closure reconfiguration are summarized below, and are presented in detail in the Final Fate and Transport Modeling of Volatile Organic Compounds at the Rocky Flats Environmental Technology Site (K-H, 2004f). Model results for PSA 5 (Mound Site/Oil Burn Pit #2) and PSA 12 (IA Plume) are exceptions and have been modified since the VOC modeling report to incorporate changes made to the post-January 2004 land configuration. The new model results for these PSAs are presented in Appendix E.

Modeling Results – FY03 Conditions

The current distribution of VOCs for each PSA was evaluated using a groundwater flow path analysis and a sensitivity analysis of reactive transport for the PCE and CT degradation chains. The results confirm initial assumptions about possible VOC source locations, the number of sources, timing of sources, and groundwater pathways and travel velocities. Flow path analysis resulted in 22 different source areas that explained concentration distributions in the 19 separate areas. Results are consistent with groundwater sources being introduced approximately 30 to 50 years ago.

Modeling shows that three-dimensional groundwater flows are important in supporting a detailed flow and transport model for the Site. Vertical gradients are downward in pediment areas, but are upward near the bottom of hillslopes or streams due to the hillslope structure and UHSU groundwater flow through weathered bedrock. This is important in the conceptual model because slower flow rates from sources allow for more efficient degradation (mostly within weathered bedrock) before it eventually emerges at stream areas. Because ET dominates near-stream hydrology at RFETS, model results indicated increasing amounts of VOCs in groundwater were lost via ET near streams. This loss to ET was significant because it helped attenuate VOCs in groundwater within most PSAs before discharging as baseflow to streams, seeps, ponds, or overland flow.

Model Results – Proposed Closure Configuration

In four of the eight PSAs modeled, at least one of the closure-condition simulations for each area produced long-term groundwater concentrations of TCE or CT that would be above the draft SWPRGs at groundwater discharge areas. These PSAs include:

- East Trenches area (IHSS Group 900-12);

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- Mound Site/Oil Burn Pit #2 (IHSSs 113/153);
- Carbon Tetrachloride Plume (IHSS 118.1); and
- Ryan's Pit/903 Pad area (IHSSs 109/112).

Of these areas, only the Carbon Tetrachloride Plume would have an average groundwater concentration (for all closure-condition simulations) below the draft SWPRG at groundwater discharge areas.

In general, simulated results indicate that only parent compounds CT and TCE would be above SWPRGs at groundwater discharge areas. All daughter products and PCE would not. For the other PSAs not listed above, simulated groundwater VOC concentrations in groundwater discharge areas for closure simulations would be below the SWPRGs. This is due to a combination of the following:

- Slower groundwater velocities in weathered bedrock (beneath unsaturated, unconsolidated material in some upper hillslope areas);
- The combined effect of attenuation processes (such as biodegradation, sorption, volatilization, and ET loss) that reduce VOC concentrations in groundwater discharge to surface areas; and
- Loss through volatilization (not simulated with the reactive transport model but results in conservatively high concentrations).

In most PSAs, biodegradation appears to be the dominant attenuation process despite the low rates, although ET loss is more significant in the east-central BZ PSAs (i.e., southeast of the 903 Pad and in the East Trenches area). Although parameter values for each closure configuration model reproduced historical time-averaged concentrations, some combinations underestimated concentrations while others over-predicted concentrations. The latter case likely over-predicted long-term closure concentrations at groundwater discharge areas. As such, a single run should not be considered an accurate representation of closure concentrations, or even the most reasonable. Rather, the range of predicted results should be used in assessments.

4.5 Surface Water

For each of the 10 groundwater AOIs, maps were prepared for the same analytes in surface water (Figure 4-24 through Figure 4-33). Data were queried from SWD for samples collected from June 28, 1991 through August 31, 2004. At locations where more than one sample was collected, the most recent sample result is displayed on the figure. It should be noted that surface water samples, especially for VOCs and nitrate, have been collected infrequently at RFETS.

Data are displayed to parallel the requirements of the RAOs described in Section 1.6. Colored dots on the maps distinguish between locations with the following sample results:

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- Non-detectable concentration;
- Concentration greater than or equal to the RFCA surface water standard (or the PQL if lower than the RFCA standard) and less than the SWPRG;
- Concentration greater than the SWPRG; and
- Concentration greater than 10 times the SWPRG.

Figure 4-24 through Figure 4-33 indicate that all of the AOIs have been detected in surface water at concentrations above their respective surface water standards, although the frequency of detection above the standard varies by AOI. An evaluation of surface water quality, and specifically a review of areas where the AOIs measured in surface water exceed their surface water standards because of impacts from groundwater contamination, is presented in the RAO 3 screening discussion in Section 5.5.

4.6 Accelerated Actions Previously Completed

Several accelerated actions have already been completed with the intent to improve groundwater quality. These actions can be categorized into three types of remedial action:

- Soil removal actions;
- In-situ soil treatment actions; and
- Groundwater collection and treatment actions.

The previously completed accelerated actions are summarized in Table 4-2. These actions are taken into consideration with the screening step that considers previous remedial actions, when evaluating which areas of groundwater contamination should be considered for an alternatives analysis for additional action. That screening step evaluation is presented in Section 5.6.

Table 4-2. Accelerated Actions Previously Completed

Action Type	Location	Nature of Contamination	Description of Accelerated Action	Year Completed
Soil Removal	Mound Site (IHSS 113)	PCE, TCE	Excavated soils were treated with thermal desorption units to remove VOCs from the soil. Treated soil returned to excavation.	1997
	SPP (IHSS 101)	Nitrate, U	Sludge removal.	1995
	East Trenches (IHSS Group 900-12)	PCE, TCE, CT	Excavated soils were treated with thermal desorption units to remove VOCs from the soil. Treated soil returned to excavation.	1996

(continued on next page)

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(Table 4-2 continued)

Action Type	Location	Nature of Contamination	Description of Accelerated Action	Year Completed
Soil Removal[1]	Ryan's Pit (IHSS 109)	PCE, TCE	Excavated soils were treated with thermal desorption units to remove VOCs from the soil. Treated soil returned to excavation.	1996
	903 Pad	VOCs, Nitrate, U	Soil removal action performed for radionuclides, but other contaminants also removed.	2003
	Building 443	Fuel oil	Four underground storage tanks containing No. 6 fuel oil for the steam plant were removed in 2004. Contaminated adjacent subsurface soil was removed when the tanks were removed.	2004
	IA	VOCs	Multiple separate soil removal actions.	Range
In-Situ Soil Treatment[2]	PU&D Yard Plume (IHSS 170)	PCE	Boreholes completed and utilized as insertion points for a one-time application of Hydrogen Release Compound™, which stimulates enhanced natural attenuation.	2003
Groundwater Collection and Treatment	Mound Site (IHSS 113) and Oil Burn Pit #2 (IHSS 153)	PCE, TCE	Construction of passive collection trench and two gravity flow zero-valent iron groundwater treatment cells.	Construction completed in 1998; treatment ongoing
	East Trenches Plume (IHSS Group 900-12)	PCE, TCE, CT	Construction of passive collection trench and two gravity flow zero-valent iron groundwater treatment cells.	Construction completed in 1999; treatment ongoing
	SEP Plume (IHSS 101) and 700 Area N.E. Plume	Nitrate, U VOCs	Construction of passive collection system with two treatment cells. The first cell (filled with a mixture of sawdust, leaf mold, and 10% zero-valent iron) is designed to induce denitrification and remove uranium. A second cell is filled with zero-valent iron to act as a final polisher.	Construction completed in 1999; treatment ongoing
	OU1 (IHSS 119.1)	PCE, TCE	Construction of a French drain and extraction well; collected water was treated at Building 891. Groundwater capture and treatment system decommissioned as per OU1 CAD/ROD.	1992

Notes:

1) Soil removal is being conducted at the Carbon Tetrachloride Plume (IHSS 118.1). However, that project is currently ongoing and is therefore not included in this table of previously completed actions. .

2) In-situ soil treatment, is being conducted at the Carbon Tetrachloride Plume (IHSS 118.1), and involves the use of Hydrogen Release Compound™ added to soil with residual contamination. However, that project is currently ongoing and is therefore not included in this table of previously completed actions.

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4.7 Summary of Nature and Extent of Contamination

In summary, 10 groundwater AOIs addressed by this nature and extent of contamination section are being further evaluated. These are 1,1-DCE, CT, CF, cis-1,2-DCE, MC, PCE, TCE, VC, uranium, and nitrate.

The presence of AOIs in groundwater, subsurface soil, and surface water is summarized in Table 4-3. Contaminant source areas are identified based on distinct locations with an apparent source of groundwater contamination. The remarks presented in the table address the nature of contamination in all media, as well as the apparent extent of groundwater contamination. The far right column provides an indication, based on the nature and extent of contamination, whether the contaminant source area should be included in the areas further evaluated.

Several factors were assessed in the recommendation for a specific area to be further evaluated. These include the detection of AOIs in groundwater, subsurface soil, and surface water; the spatial extent of groundwater contamination; and the concentration of groundwater contamination. Those contaminant areas identified as warranting further evaluation are addressed in Section 5.0.

Table 4-3. Environmental Media Summary - AOIs

Contaminant Area	AOI Detected In:			Remark	Evaluate Area Further?
	Ground-water?	Subsurface Soil?	Surface Water?		
Carbon Tetrachloride Plume (IHSS 118.1)	Yes	Yes	Yes	VOCs detected in all media. Relatively large CT plume extent.	Yes
East Trenches (IHSS Group 900-12)	Yes	Yes	Yes	VOCs detected in all media. Relatively large VOC plume extent.	Yes
SEPs (IHSS 101)	Yes	Yes	Yes	Nitrate, uranium detected in all media. Relatively large nitrate and uranium plume extents.	Yes
700 Area Northeast Plume	Yes	Yes	No	VOCs, nitrate detected in sub-surface soil, groundwater. Groundwater concentrations above 10 x SWPRG.	Yes
Mound (IHSS 113)	Yes	Yes	Yes	VOCs detected in all media. Relatively moderate plume extent. Groundwater concentrations above 10 x SWPRG.	Yes

(Table continued next page)

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(Table 4-3 continued)

Contaminant Area	AOI Detected in:			Remark	Evaluate Area Further?
	Ground-water?	Subsurface Soil?	Surface Water?		
Oil Burn Pit #2 (IHSS 153)	Yes	Yes	Yes	VOCs detected in all media. Groundwater concentrations above 10 x SWPRG.	Yes
903 Pad (IHSS 112)	Yes	Yes	Yes	VOCs detected in all media. Relatively large plume extent. Groundwater concentrations above 10 x SWPRG.	Yes
Ryan's Pit (IHSS 109)	Yes	Yes	Yes	VOCs detected in all media. Relatively large plume extent. Groundwater concentrations above 10 x SWPRG.	Yes
OU1 (IHSS 119.1)	Yes	Yes	Yes	VOCs detected in all media. Groundwater concentrations above 10 x SWPRG.	Yes
IA Plume	Yes	Yes	Yes	VOCs detected in all media. Relatively large plume extent.	Yes
PU&D Yard (IHSS 170)	Yes	Yes	Yes	VOCs, nitrate detected in subsurface soil, groundwater. Plume levels slightly above surface water standard.	Yes
Oil Burn Pit #1 (IHSS 128)	Yes	Yes	No	VOCs, nitrate detected in sub-surface soil, groundwater. VC above 10 x SWPRG.	Yes
Building 443	Yes	Yes	No	VOCs detected in sub-surface soil; groundwater contamination isolated due to nature of product. No. 6 fuel oil is not an AOI.	No
Building 444	Yes	Yes	No	VOCs, nitrate detected in sub-surface soil, groundwater. Relatively moderate VOC plume extent.	Yes
Building 991	Yes	Yes	Yes	VOCs detected in all media, but small relative plume extent. Relatively small groundwater AOI concentrations.	No

Note:

The Present Landfill and Original Landfill areas are not addressed in this IM/IRA. They are addressed in separate IM/IRAs for each area.

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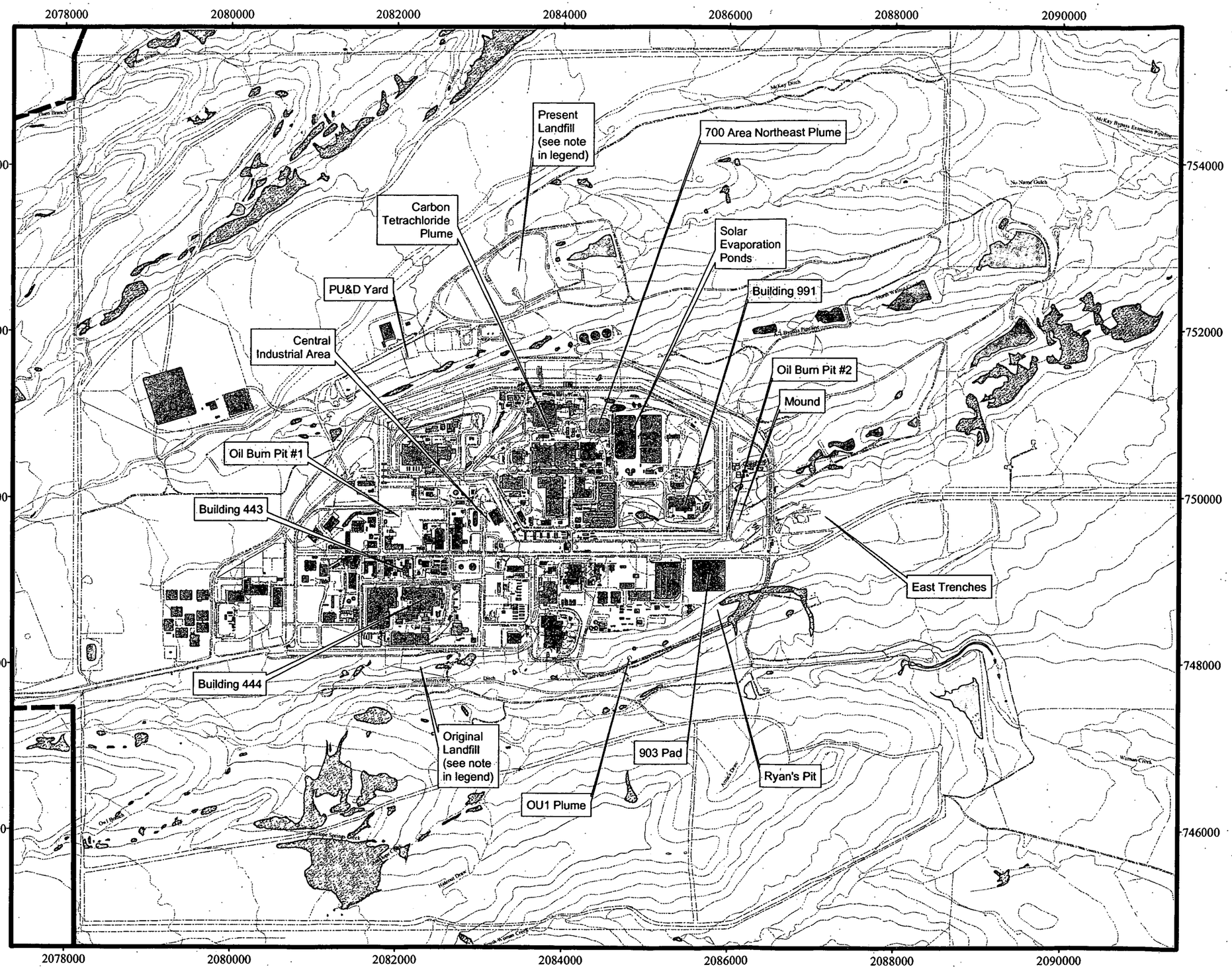

Figure 4-1
Potential Source Areas for Groundwater Contaminants

Standard Map Features

- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Note:
The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: November 30, 2004

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Prepared for:

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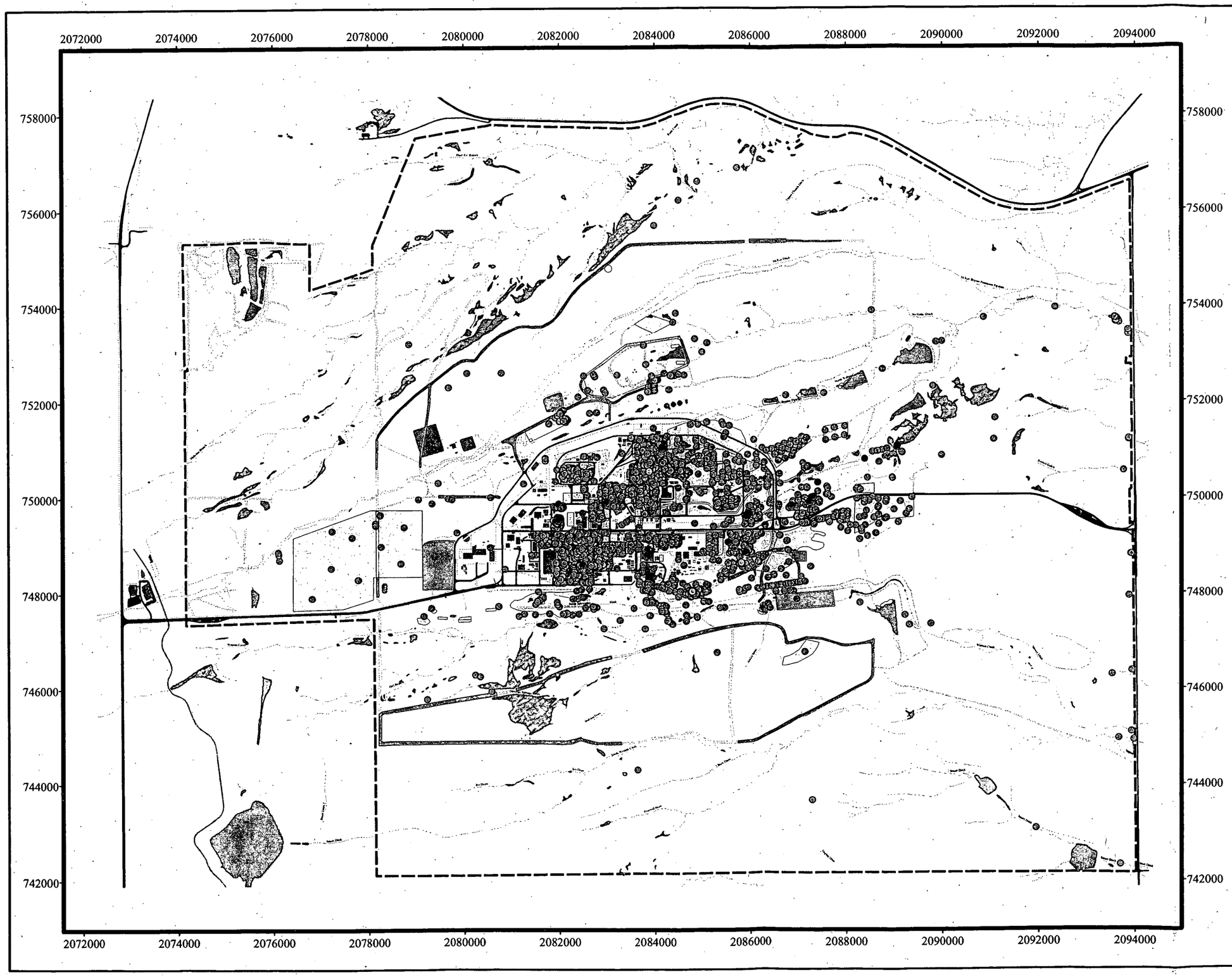

Figure 4-2
Subsurface Soil - 1,1-Dichloroethene

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 9/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: December 6, 2004

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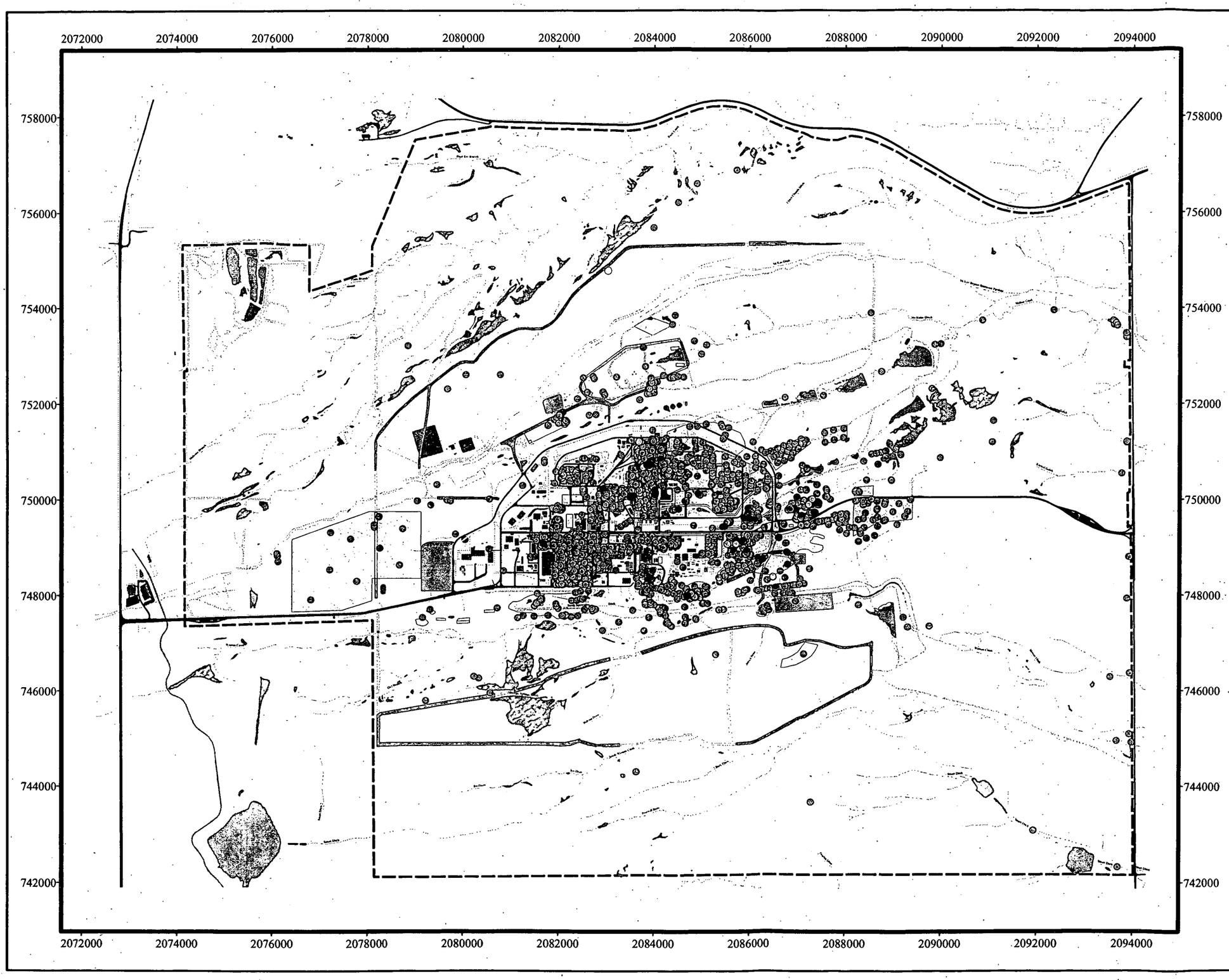

Figure 4-3
Subsurface Soil - Carbon Tetrachloride

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 9/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

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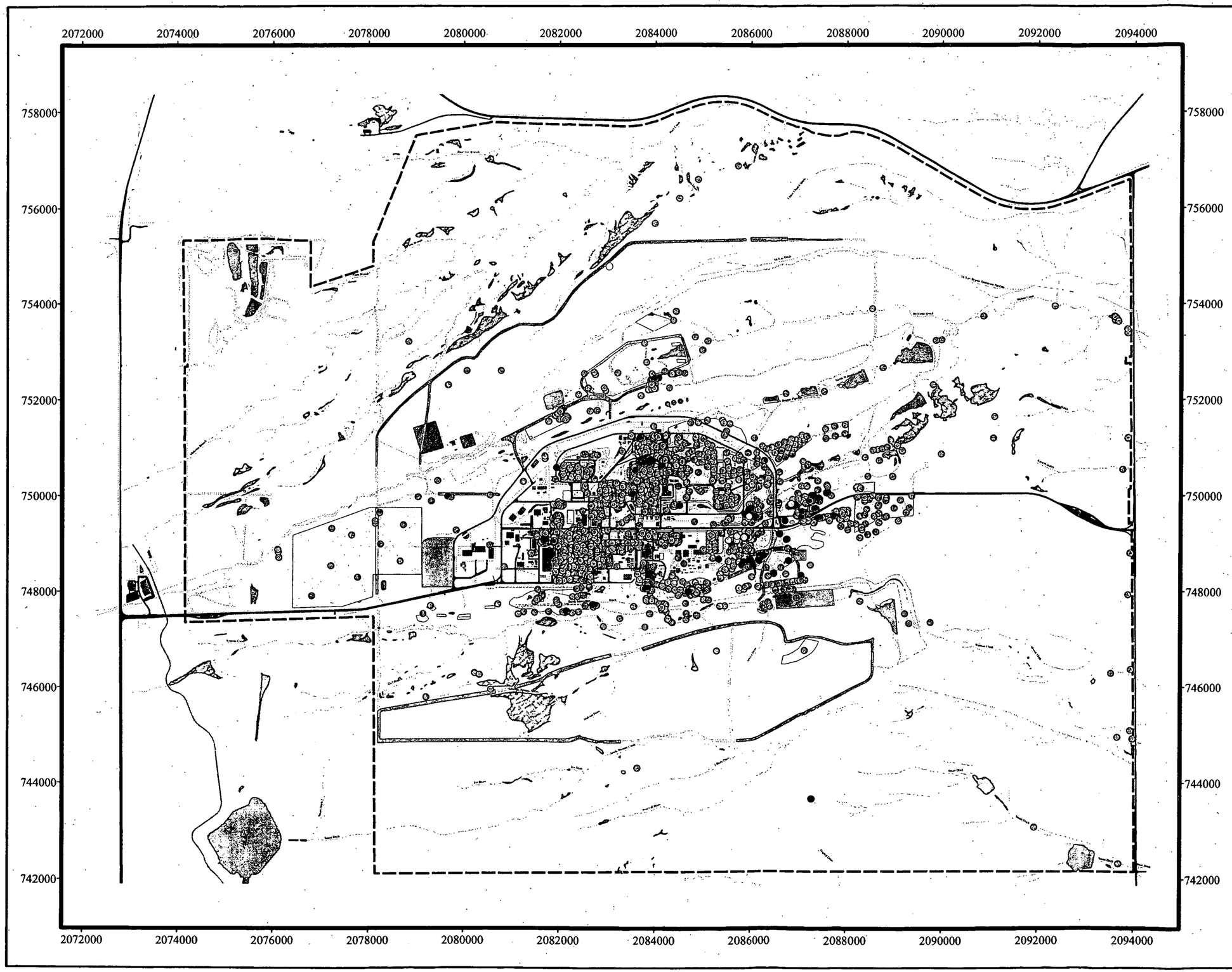

Figure 4-4
Subsurface Soil - Chloroform

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 9/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

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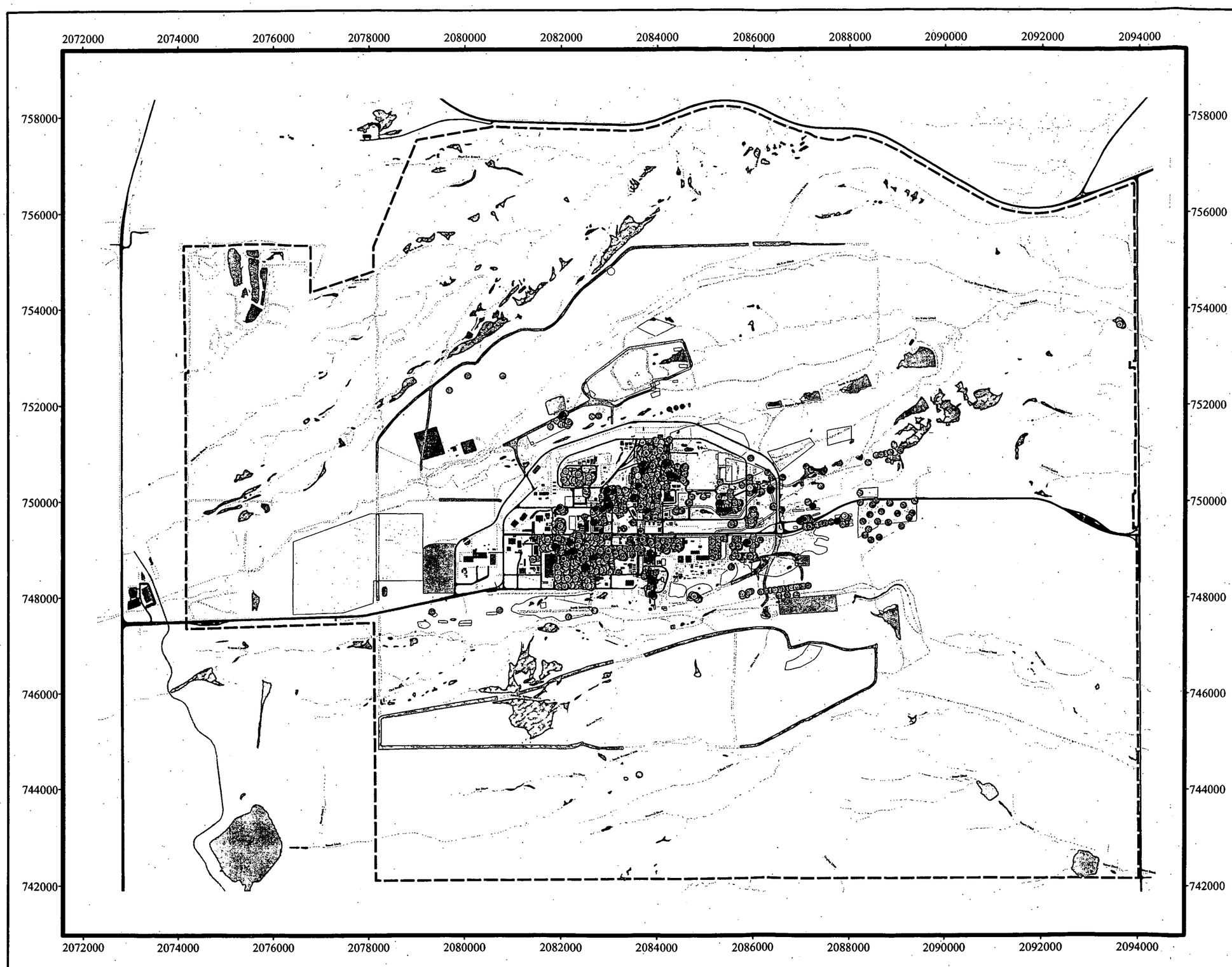

Figure 4-5
Subsurface Soil - cis-1,2-Dichloroethene

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 8/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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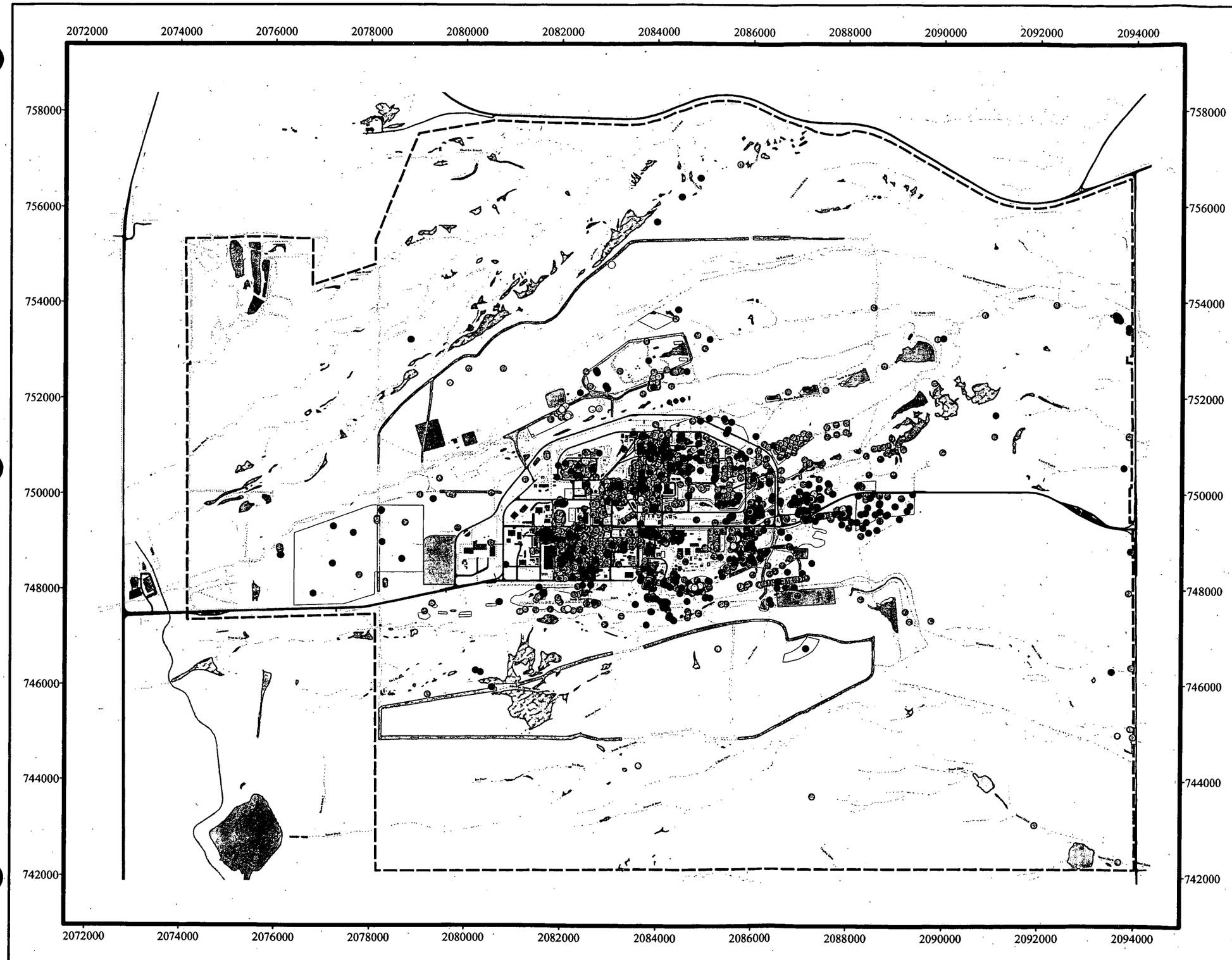

Figure 4-6
Subsurface Soil - Methylene Chloride

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 9/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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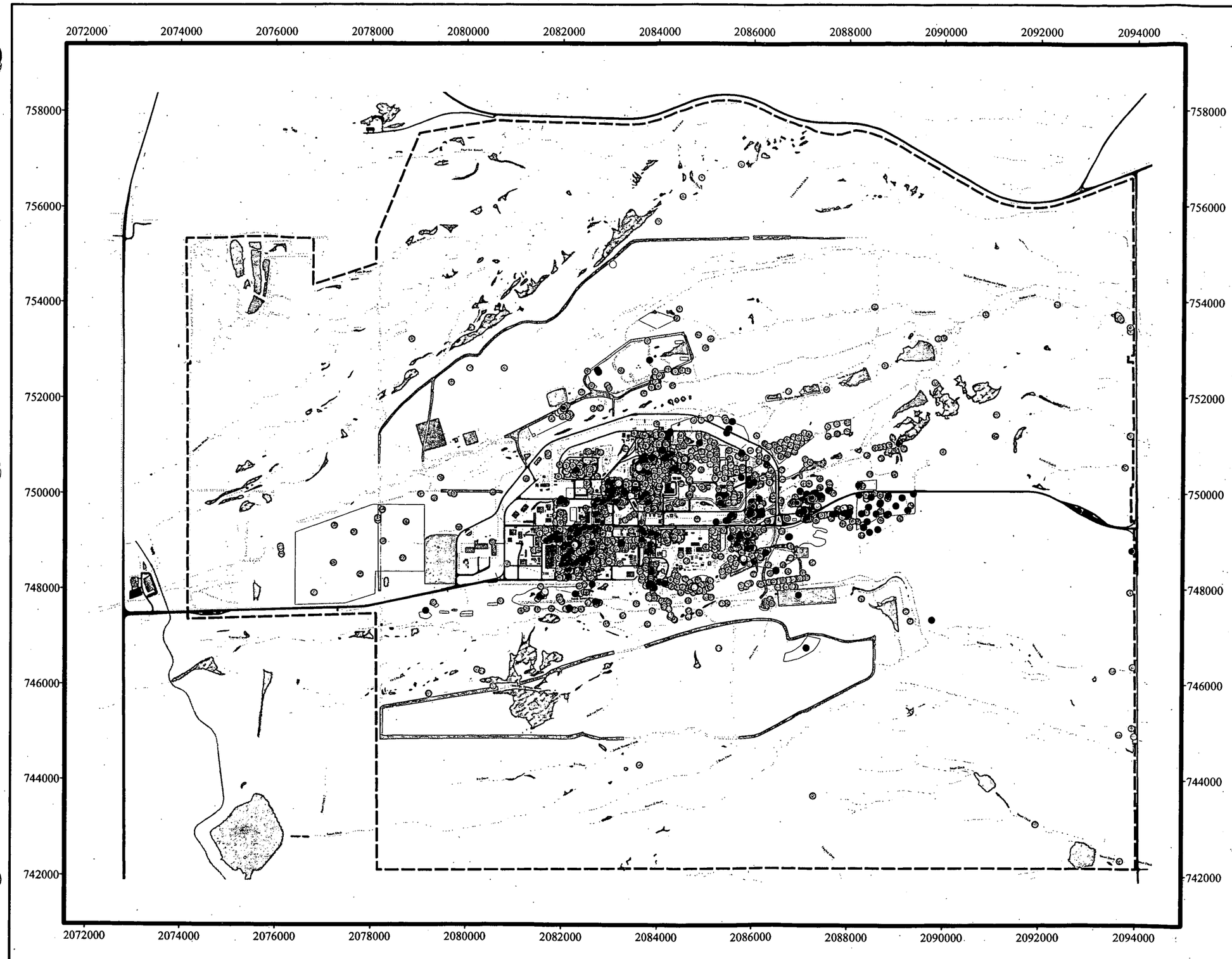

Figure 4-7
Subsurface Soil - Tetrachloroethene

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 9/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
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Datum: NAD27

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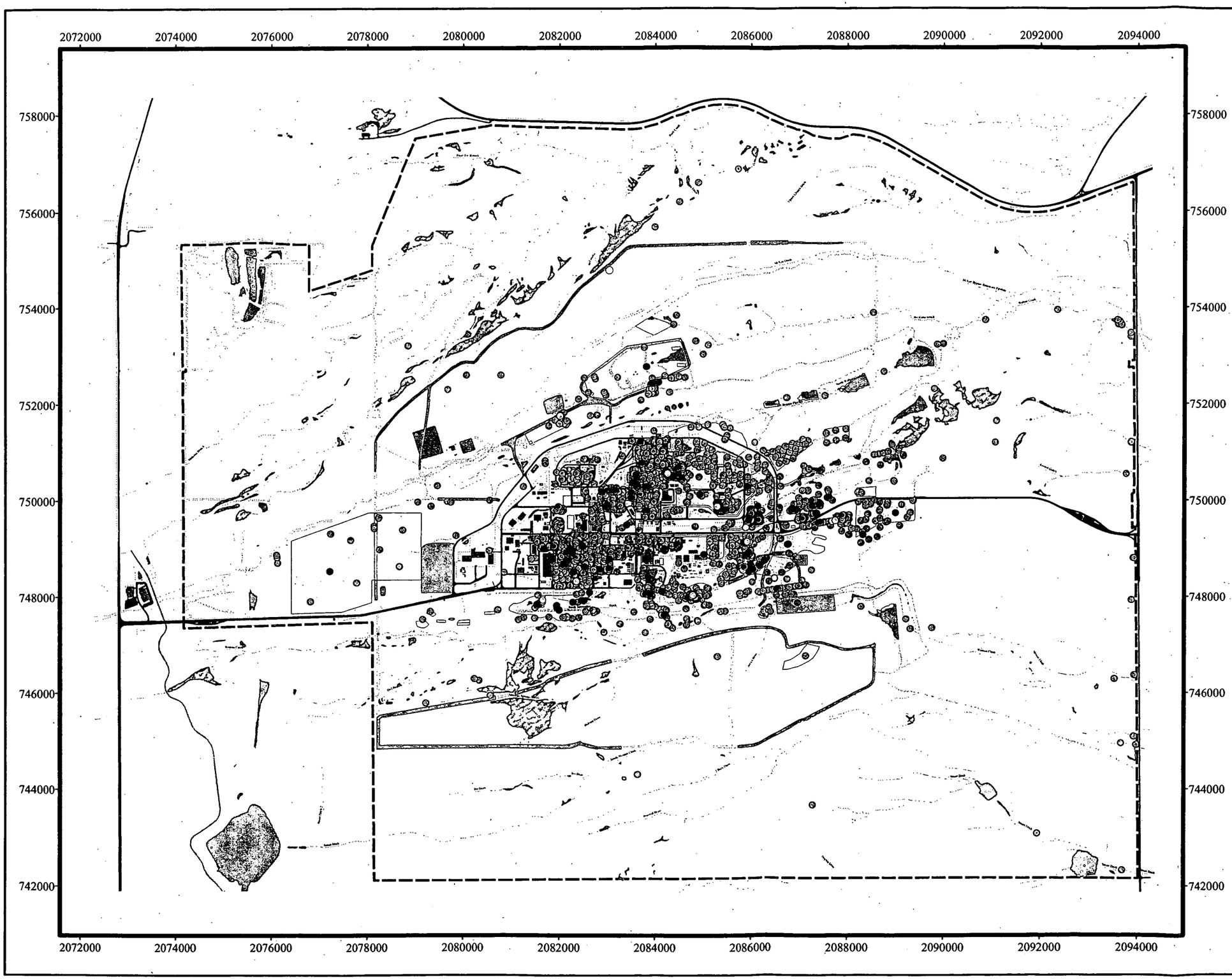

Figure 4-8
Subsurface Soil
Trichloroethene

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 6/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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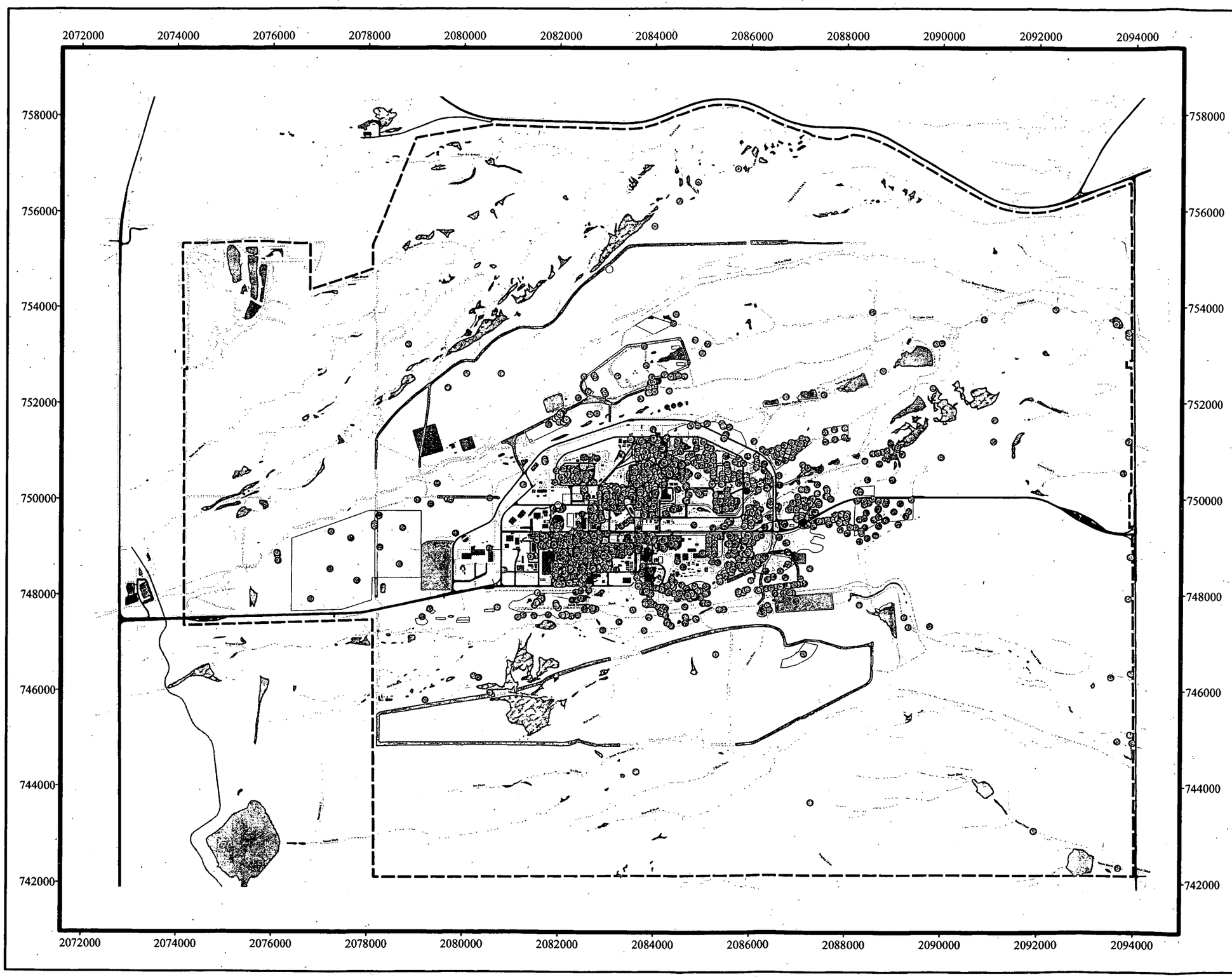

Figure 4-9
Subsurface Soil
Vinyl Chloride

Legend

- Constituent concentration > 10,000 ppb
- Constituent concentration > 1,000 ppb and < or = 10,000 ppb
- Constituent concentration > 100 ppb and < or = 1,000 ppb
- Constituent concentration > 10 ppb and < or = 100 ppb
- Constituent concentration > 0 ppb and < or = 10 ppb
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 8/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale in Feet

Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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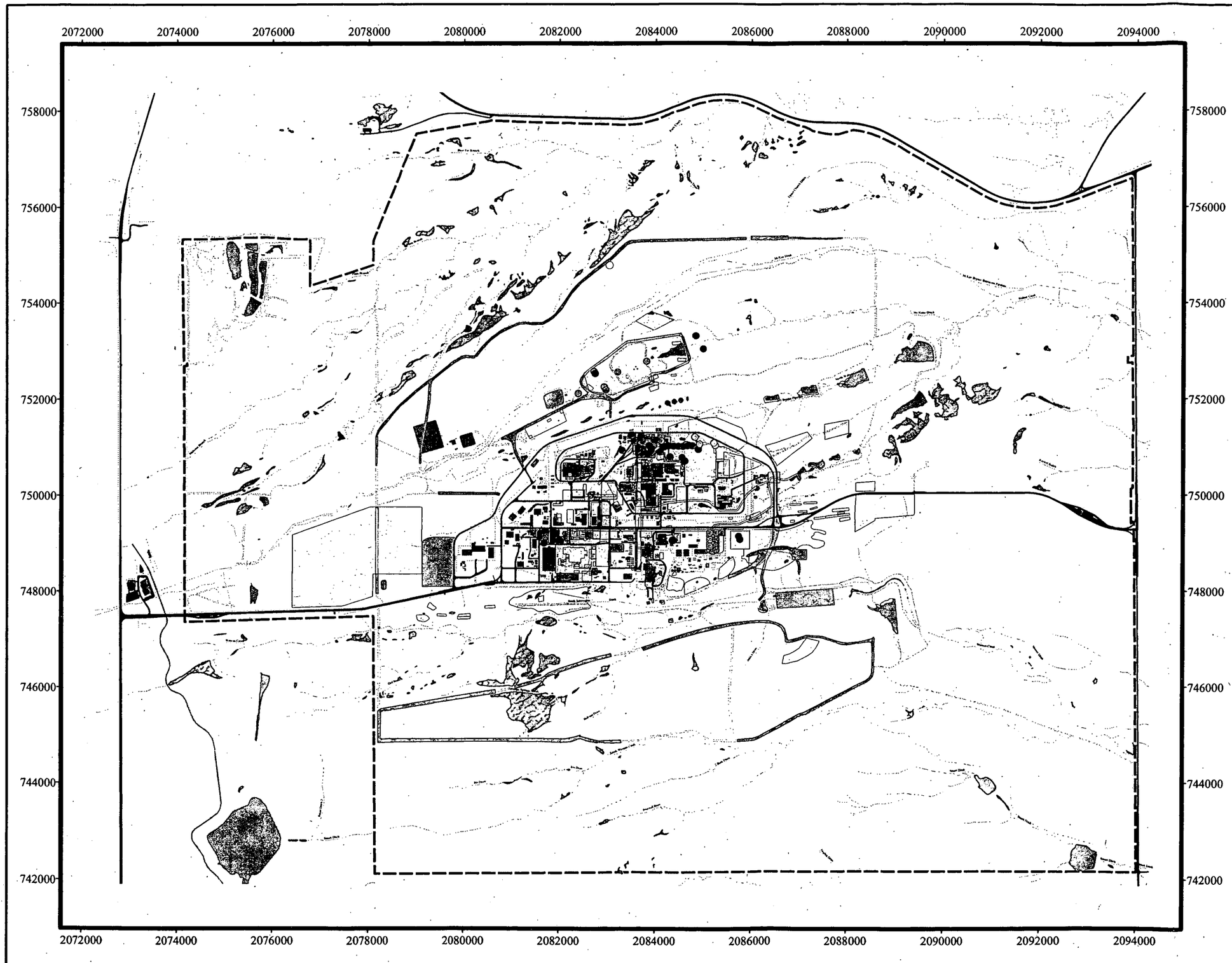

Figure 4-10
Subsurface Soil Nitrate/Nitrite

Legend

- Constituent concentration > 10,000 ppm
- Constituent concentration > 1,000 ppm and < or = 10,000 ppm
- Constituent concentration > 100 ppm and < or = 1,000 ppm
- Constituent concentration > 10 ppm and < or = 100 ppm
- Constituent concentration > 0 ppm and < or = 10 ppm
- Constituent not detected

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 8/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
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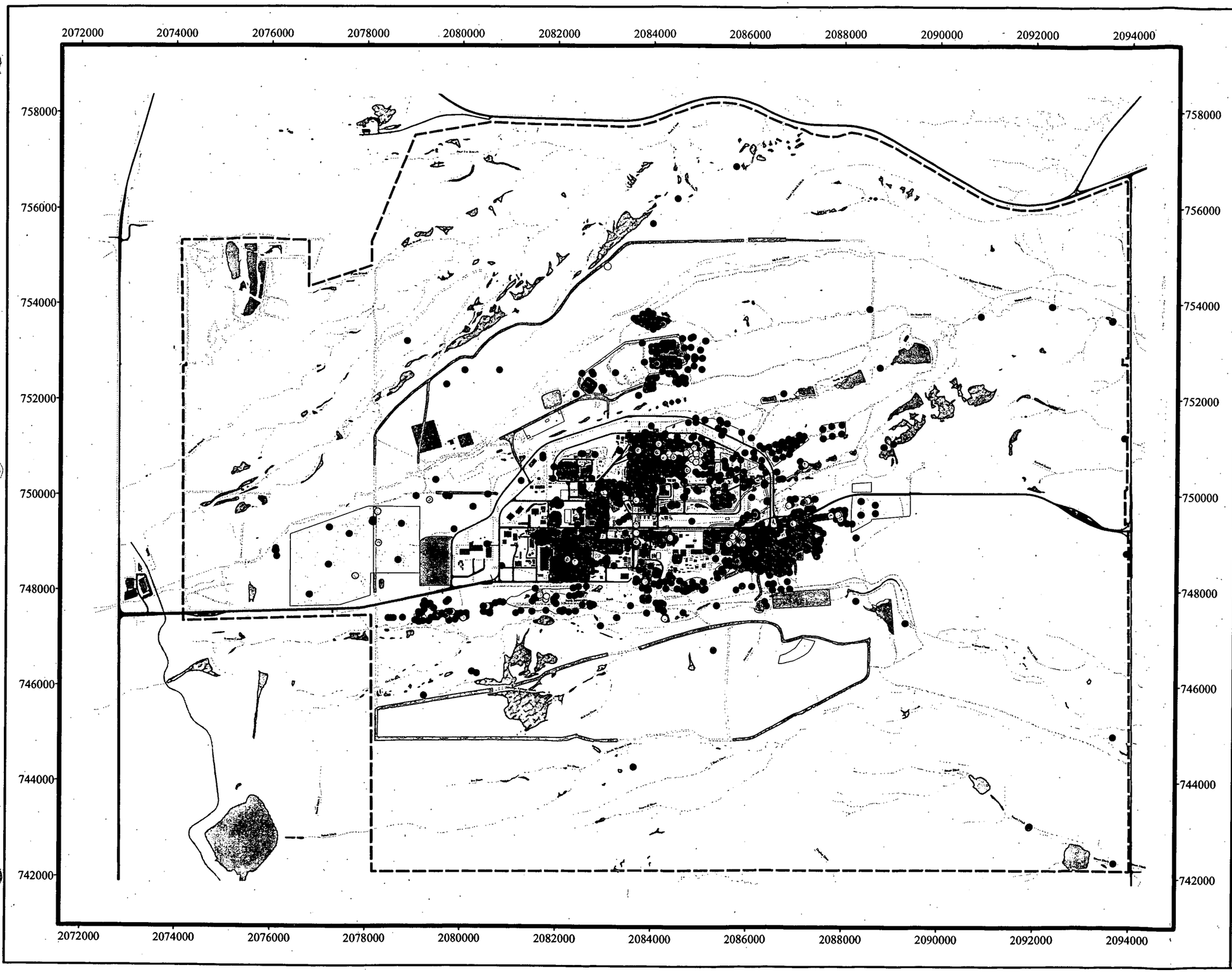

Figure 4-11
Subsurface Soil
Sum of Uranium Isotopes

Legend

- Constituent concentration > 1,000 pCi/g
- Constituent concentration > 100 pCi/g and < or = 1,000 pCi/g
- Constituent concentration > 10 pCi/g and < or = 100 pCi/g
- Constituent concentration > 1 pCi/g and < or = 10 pCi/g
- Constituent concentration < or = 1 pCi/g

Note:
Data presented are the results from soil samples, collected at depths greater than 6 inches below the ground surface, from 6/28/91 through 8/31/04. At locations where samples were collected at multiple depths, the maximum sample result for that location is displayed on the figure.

Standard Map Features

- IHSS
- PAC
- Existing building or structure
- Demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Site boundary

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
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Figure 4-12
UHSU Groundwater, 1,1-Dichloroethene-Areal Extent

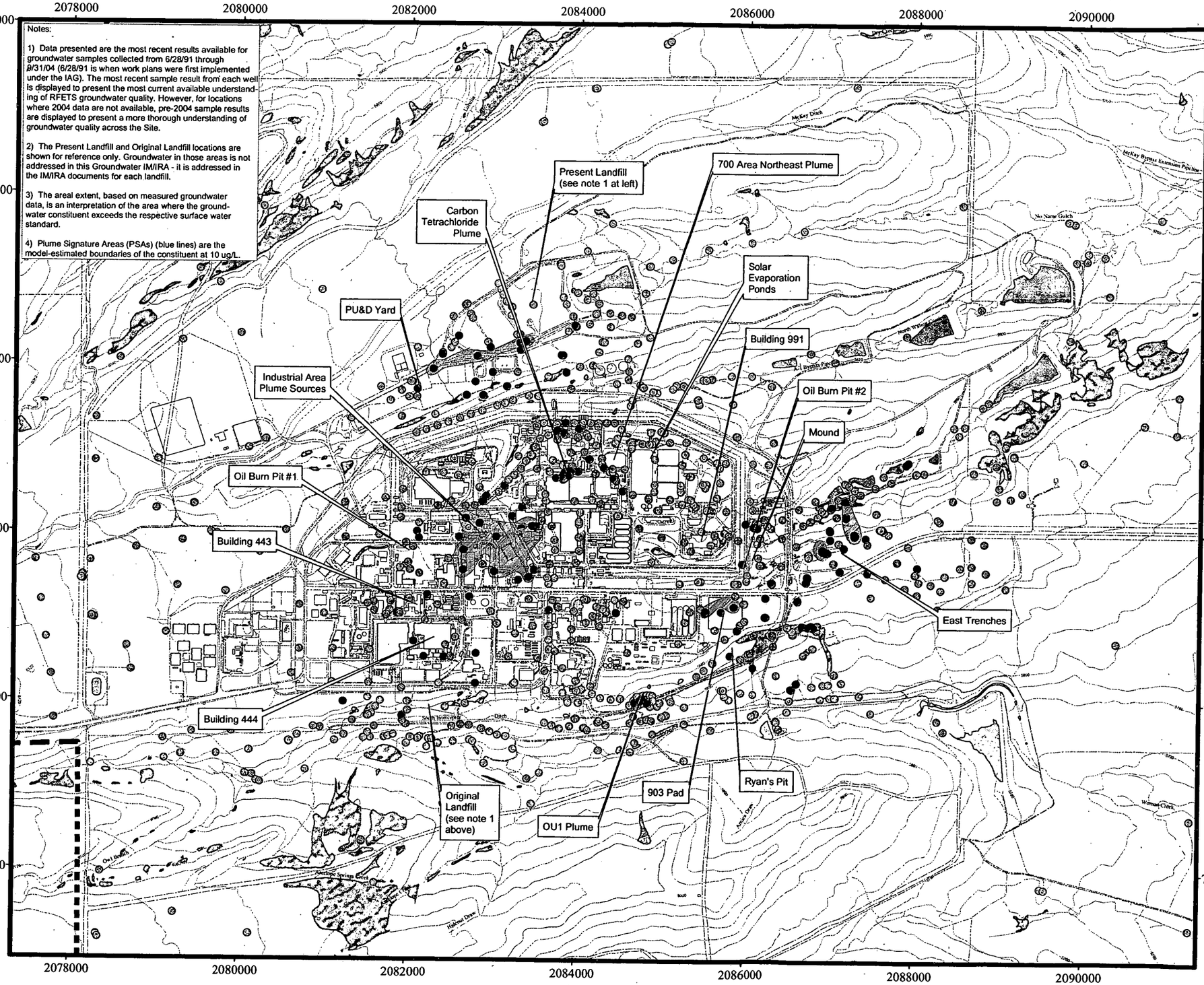
Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 9/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.



Legend

- Constituent concentration > 10 x SWPRG (1,013,890 ug/L)
- Constituent concentration > SWPRG (101,389 ug/L) and < or = 10 x SWPRG (1,013,890 ug/L)
- Constituent concentration > surface water standard (7 ug/L) and < or = SWPRG (101,389 ug/L)
- Constituent concentration < or = surface water standard (7 ug/L)
- Constituent not detected
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: December 6, 2004

URS

Prepared for:

KAISER•HILL

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Figure 4-13
UHSU Groundwater, Carbon Tetrachloride - Areal Extent

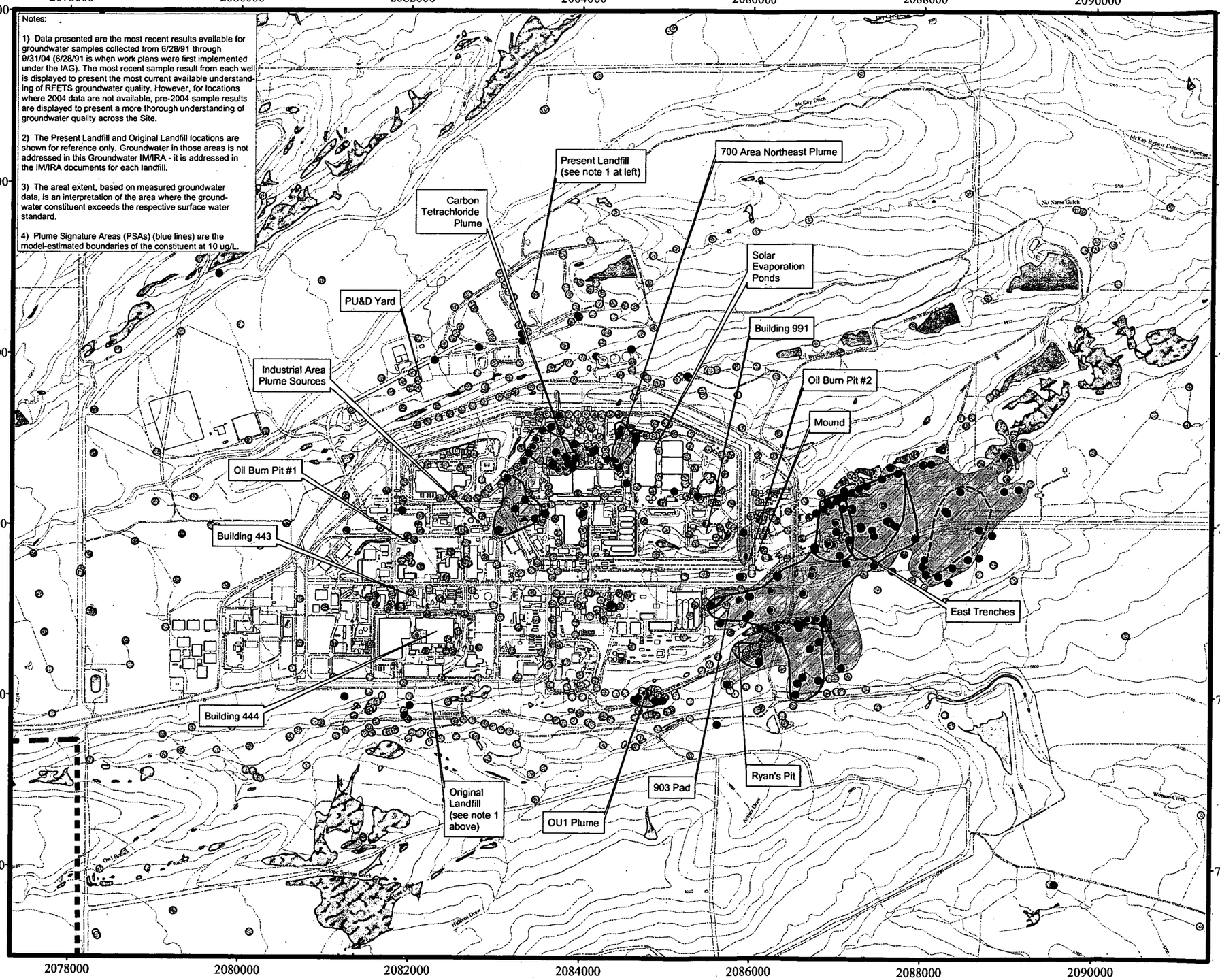
Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 9/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.



Legend

- Constituent concentration > 10 x SWPRG (5,839 ug/L)
- Constituent concentration > SWPRG (583.9 ug/L) and < or = 10 x SWPRG (5,839 ug/L)
- Constituent concentration > PQL (1 ug/L) and < or = SWPRG (583.9 ug/L)
- Constituent concentration < or = PQL (1 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for carbon tetrachloride-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for carbon tetrachloride-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: December 6, 2004

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Figure 4-14
UHSU Groundwater, Chloroform - Areal Extent

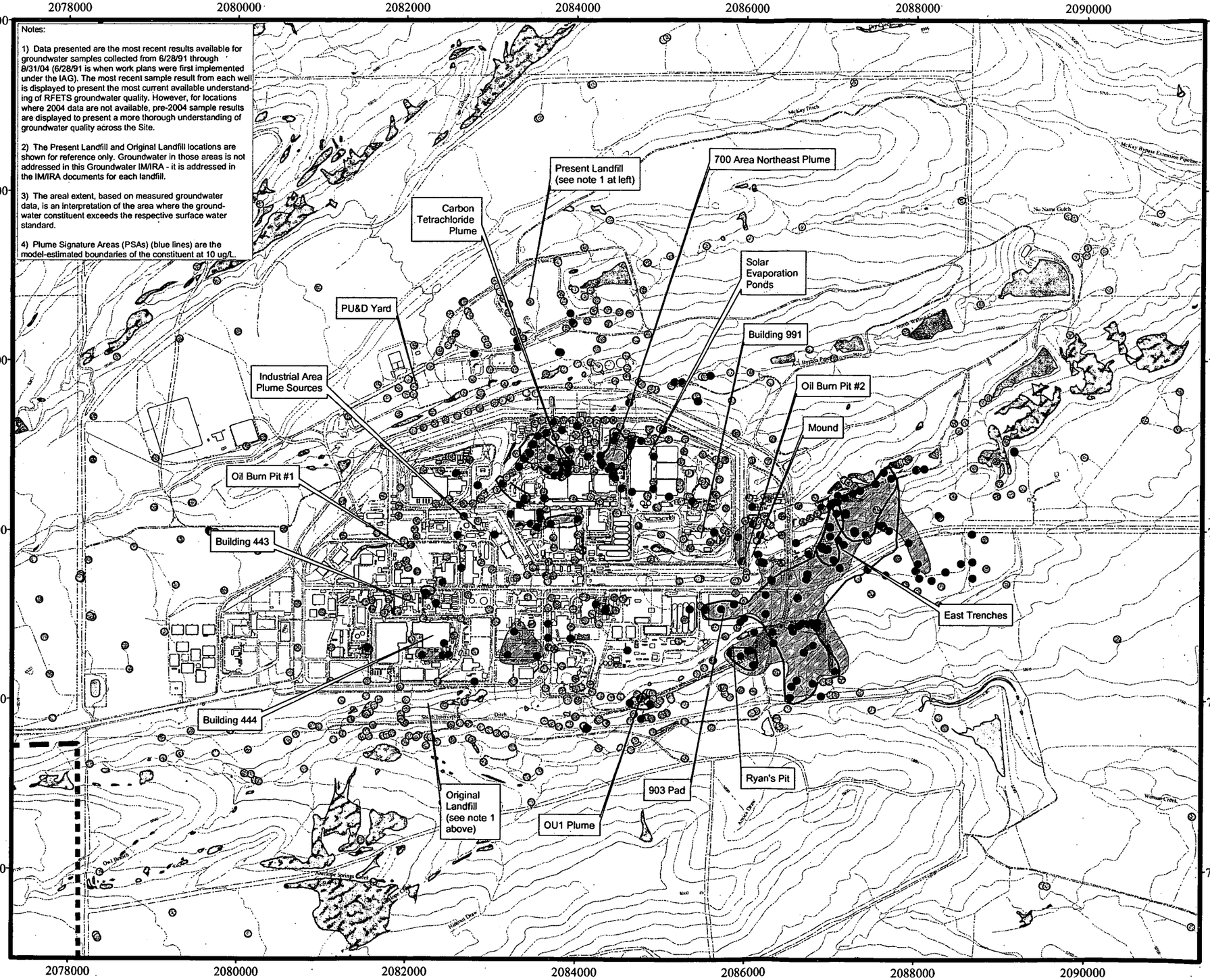
Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.



Legend

- Constituent concentration > 10 x SWPRG (202,780 ug/L)
- Constituent concentration > SWPRG (20,278 ug/L) and < or = 10 x SWPRG (202,780 ug/L)
- Constituent concentration > surface water standard (5.7 ug/L) and < or = SWPRG (20,278 ug/L)
- Constituent concentration < or = surface water standard (5.7 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for chloroform-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for chloroform-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

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Figure 4-15
UHSU Groundwater, cis-1,2-Dichloroethene - Areal Extent

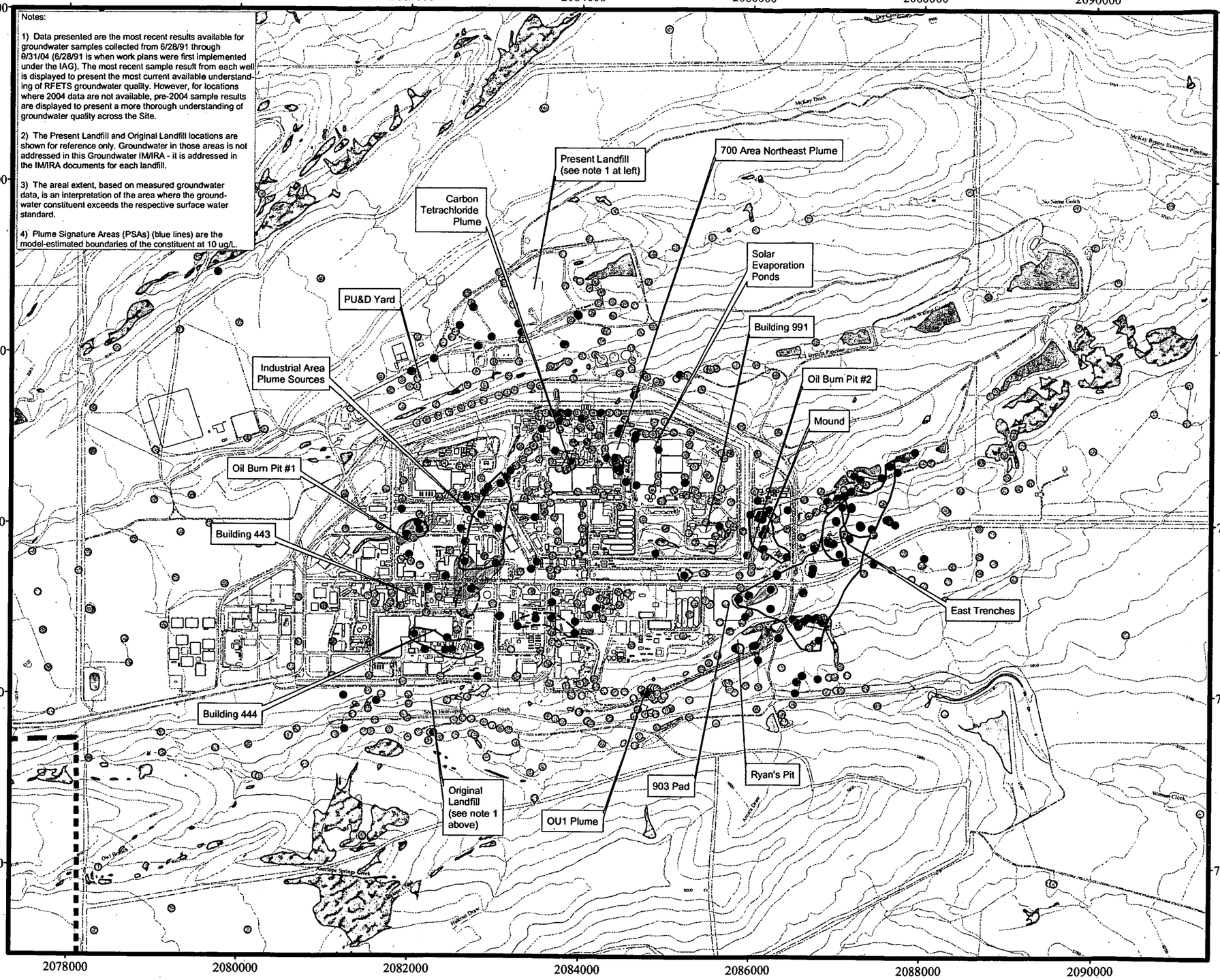
Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 6/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.



Legend

- Constituent concentration > 10 x SWPRG (182,500 ug/L)
- Constituent concentration > SWPRG (18,250 ug/L) and < or = 10 x SWPRG (182,500 ug/L)
- Constituent concentration > PQL (70 ug/L) and < or = SWPRG (18,250 ug/L)
- Constituent concentration < or = PQL (70 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for cis-1,2-Dichloroethene-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for cis-1,2-Dichloroethene-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
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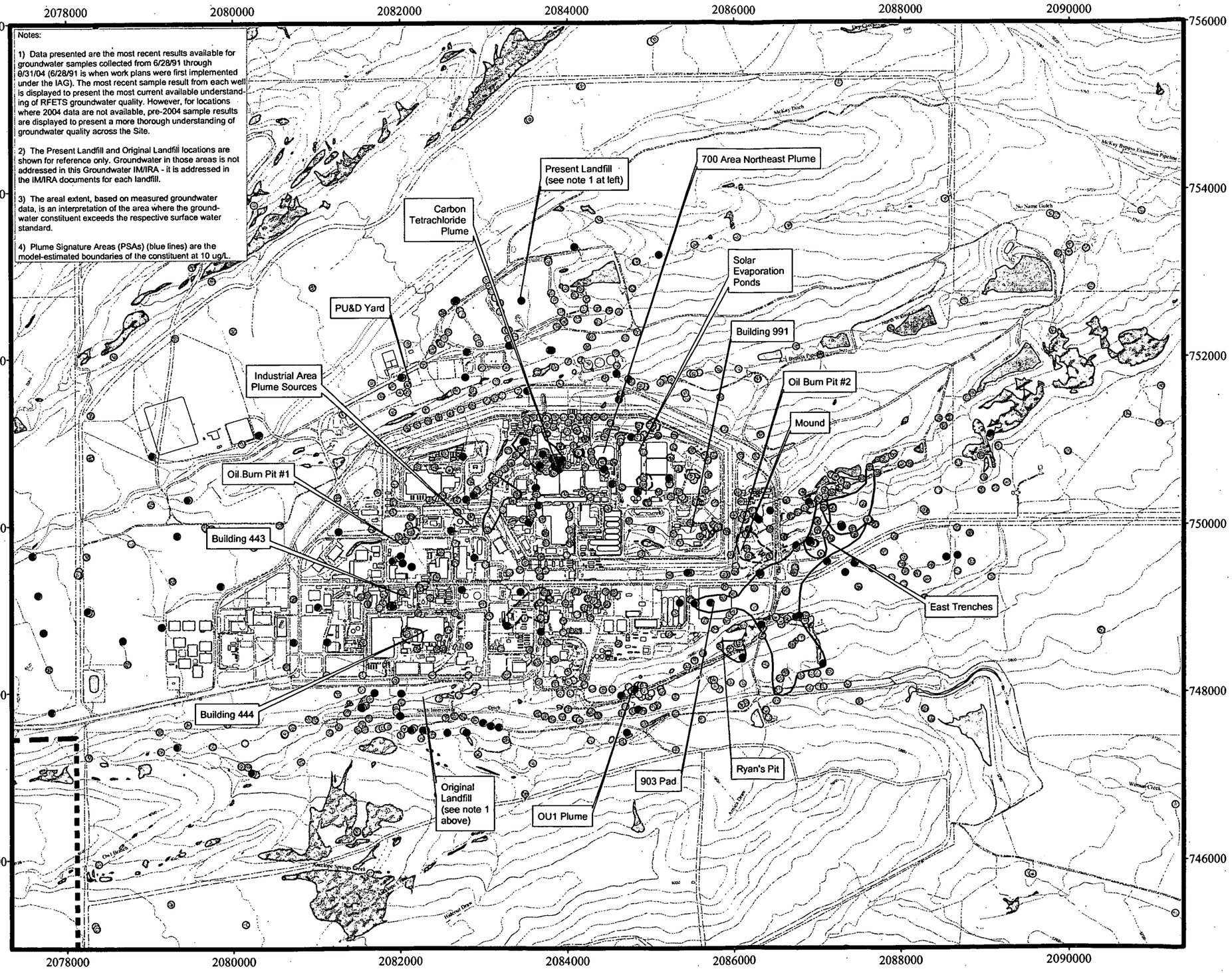
Figure 4-16
UHSU Groundwater, Methylene Chloride - Areal Extent



Legend

- Constituent concentration > 10 x SWPRG (101,210 ug/L)
- Constituent concentration > SWPRG (10,121 ug/L)and < or = 10 x SWPRG (101,210 ug/L)
- Constituent concentration > surface water standard (4.7 ug/L) and < or = SWPRG (10,121 ug/L)
- Constituent concentration < or = surface water standard (4.7 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for methylene chloride-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for methylene chloride-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
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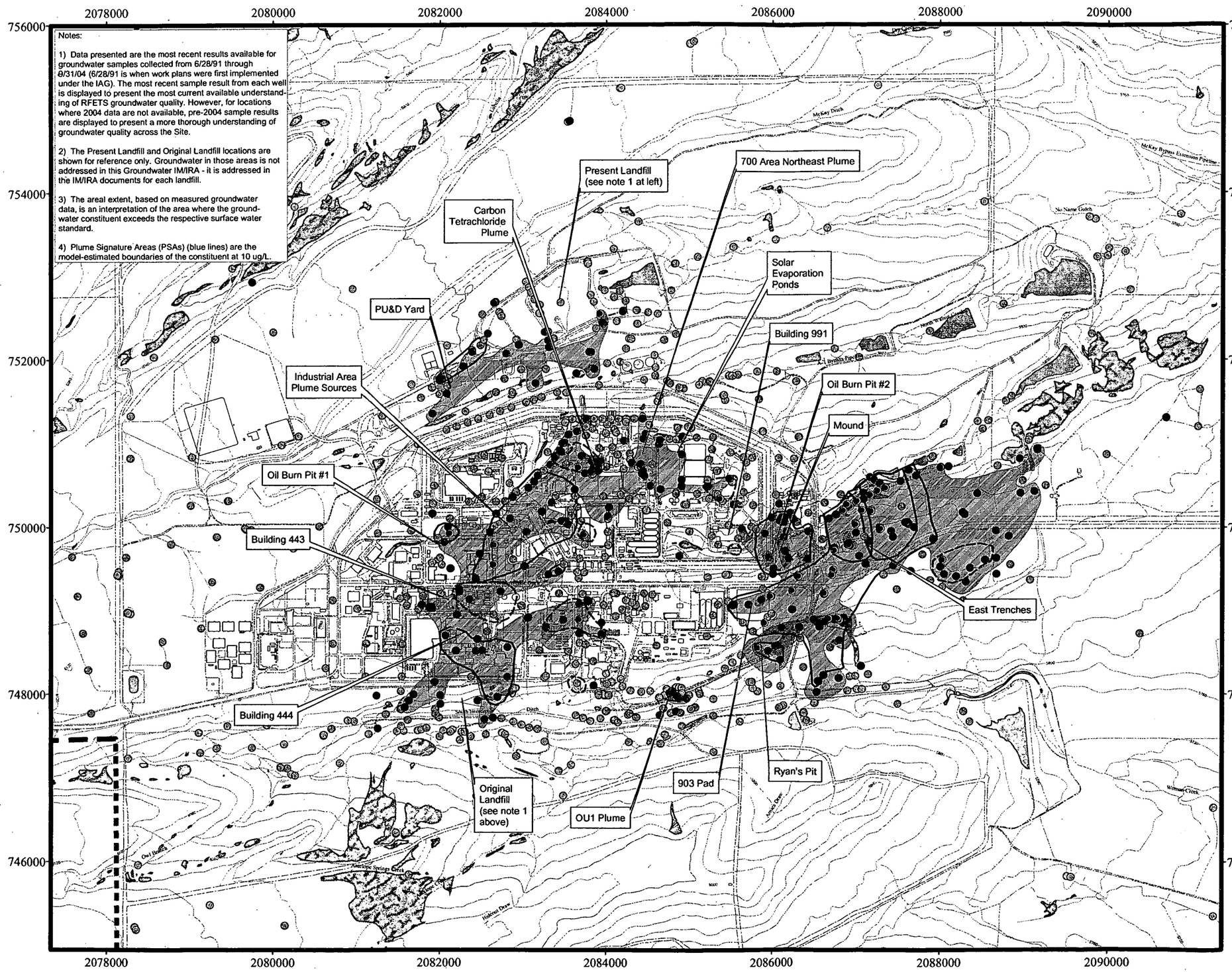
Figure 4-17
UHSU Groundwater, Tetrachloroethene - Areal Extent



Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 6/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.

Legend

- Constituent concentration > 10 x SWPRG (1,406 ug/L)
- Constituent concentration > SWPRG (140.6 ug/L) and < or = 10 x SWPRG (1,406 ug/L)
- Constituent concentration > PQL (1 ug/L) and < or = SWPRG (140.6 ug/L)
- Constituent concentration < or = PQL (1 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for tetrachloroethene-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for tetrachloroethene-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Note:
If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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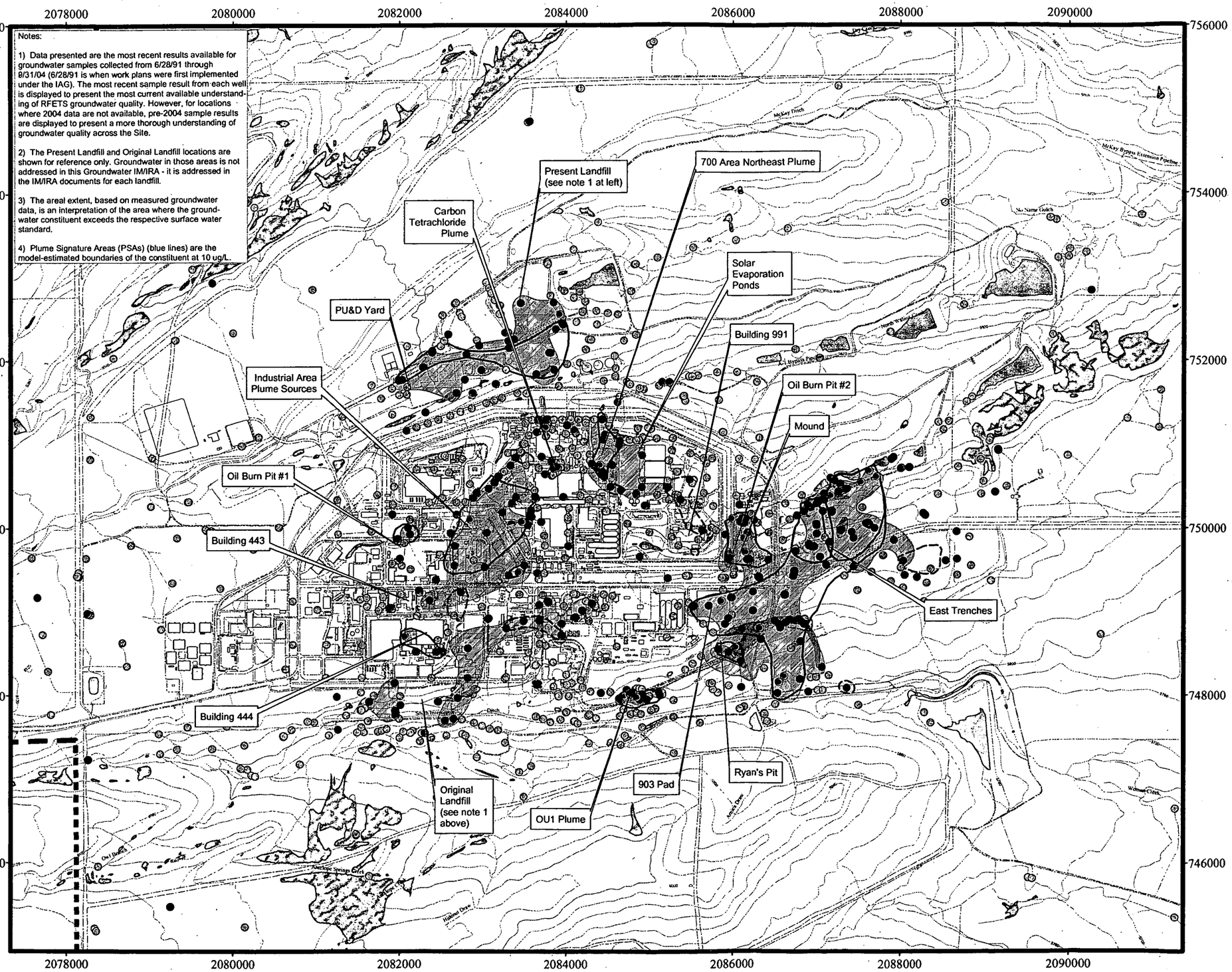
Figure 4-18
UHSU Groundwater, Trichloroethene - Areal Extent



Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.

Legend

- Constituent concentration > 10 x SWPRG (1,898 ug/L)
- Constituent concentration > SWPRG (189.8 ug/L) and < or = 10 x SWPRG (1,898 ug/L)
- Constituent concentration > surface water standard (2.7 ug/L) and < or = SWPRG (189.8 ug/L)
- Constituent concentration < or = surface water standard (2.7 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for trichloroethene-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for trichloroethene-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

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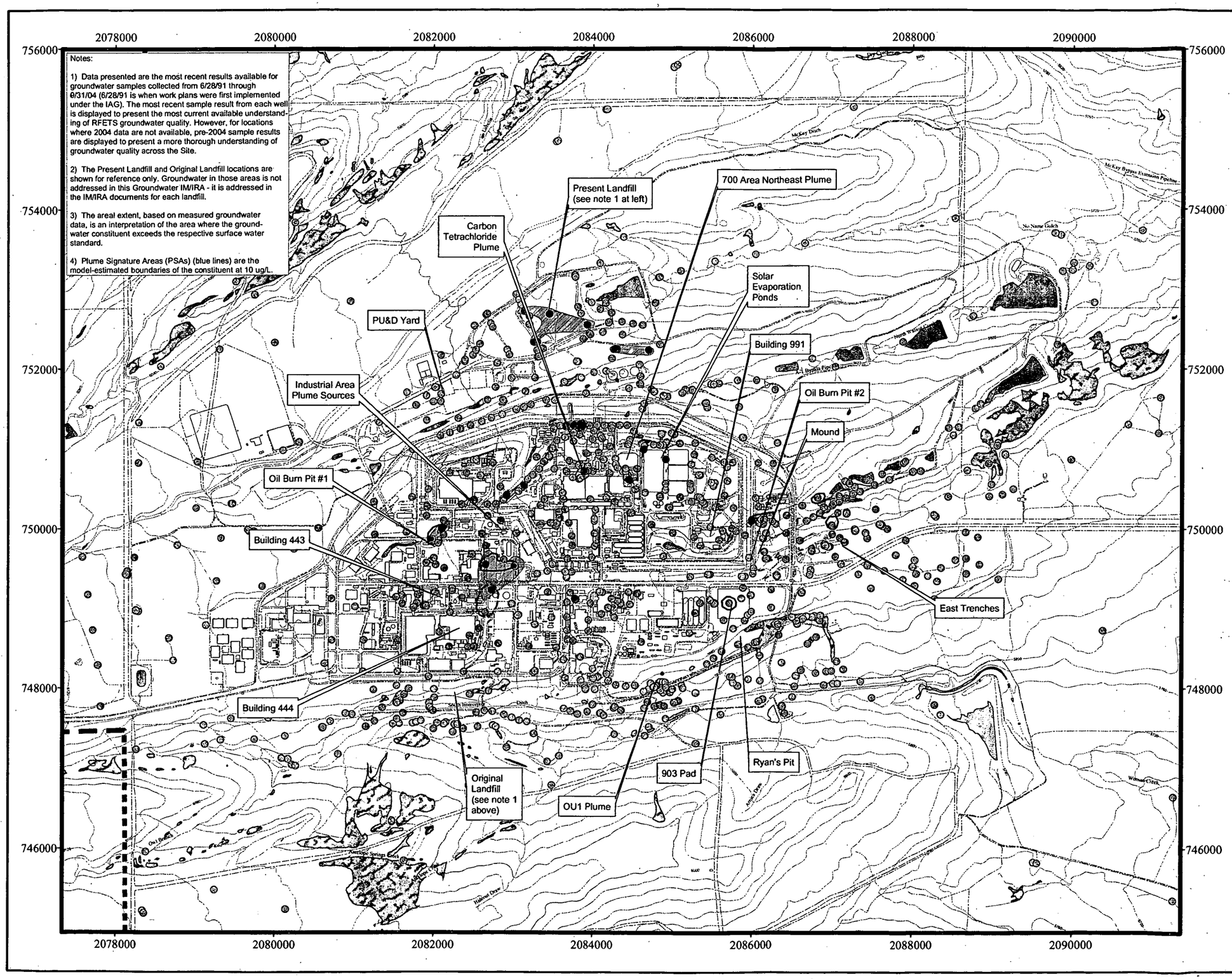

Figure 4-19
UHSU Groundwater, Vinyl Chloride - Areal Extent

Legend

- Constituent concentration > 10 x SWPRG (506 ug/L)
- Constituent concentration > SWPRG (50.6 ug/L) and < or = 10 x SWPRG (506 ug/L)
- Constituent concentration > surface water standard (2 ug/L) and < or = SWPRG (50.6 ug/L)
- Constituent concentration < or = surface water standard (2 ug/L)
- Constituent not detected
- Approximate 10 ug/L boundary for vinyl chloride-chain PSA having at least one value exceeding SWPRG
- Approximate 10 ug/L boundary for vinyl chloride-chain PSA having no values that exceed SWPRG
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

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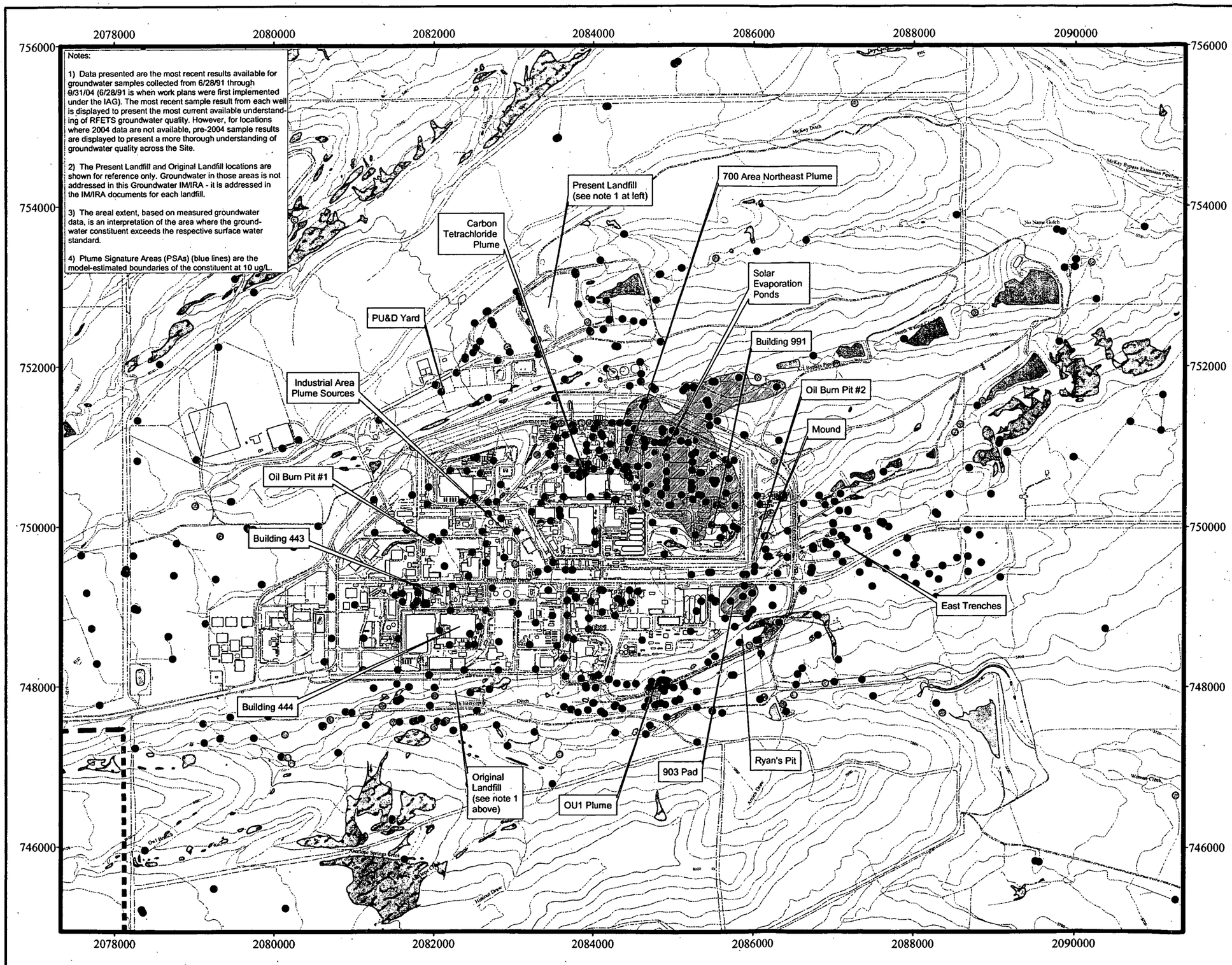
Figure 4-20
UHSU Groundwater, Nitrate/Nitrite (as N) - Areal Extent



Legend

- Constituent concentration > 10 x SWPRG (32,444 mg/L)
- Constituent concentration > SWPRG (3,244 mg/L) and < or = 10 x SWPRG (32,444 ug/L)
- Constituent concentration > surface water standard (10 mg/L) and < or = SWPRG (3,244 mg/L)
- Constituent concentration < or = surface water standard (10 mg/L)
- Constituent not detected
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

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State Plane Coordinate Projection
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Figure 4-21
UHSU Groundwater, Total Isotopic Uranium - Areal Extent

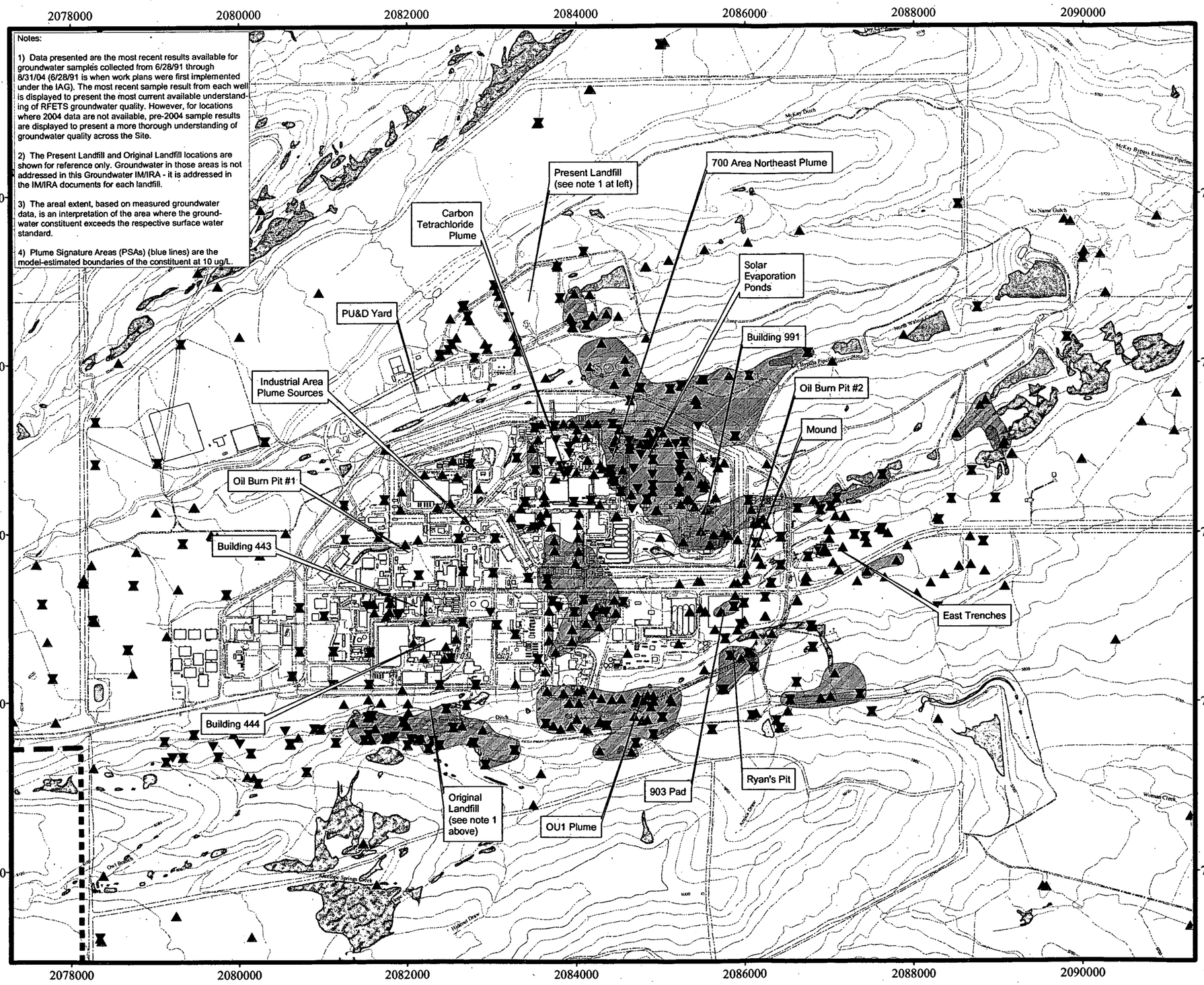
Notes:

1) Data presented are the most recent results available for groundwater samples collected from 6/28/91 through 8/31/04 (6/28/91 is when work plans were first implemented under the IAG). The most recent sample result from each well is displayed to present the most current available understanding of RFETS groundwater quality. However, for locations where 2004 data are not available, pre-2004 sample results are displayed to present a more thorough understanding of groundwater quality across the Site.

2) The Present Landfill and Original Landfill locations are shown for reference only. Groundwater in those areas is not addressed in this Groundwater IM/IRA - it is addressed in the IM/IRA documents for each landfill.

3) The areal extent, based on measured groundwater data, is an interpretation of the area where the groundwater constituent exceeds the respective surface water standard.

4) Plume Signature Areas (PSAs) (blue lines) are the model-estimated boundaries of the constituent at 10 ug/L.



Legend

- Constituent concentration > 10 x SWPRG (41,729 pCi/L)
- Constituent concentration > SWPRG (4,172.9 pCi/L) and < or = 10 x SWPRG (41,729 pCi/L)
- Constituent concentration > surface water standard (10 pCi/L) and < or = SWPRG (4,172.9 pCi/L)
- Constituent concentration < or = surface water standard (10 pCi/L)
- Constituent not detected
- Filtered Uranium data
- Unfiltered Uranium data
- Constituent concentration > 10 x SWPRG
- Constituent concentration > SW standard

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

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Scale in Feet

Scale = 1 : 14,400
1 inch represents 1,200 feet

State Plane Coordinate Projection
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Figure 4-22. Conceptual Model Diagram - Flows and VOC Transport

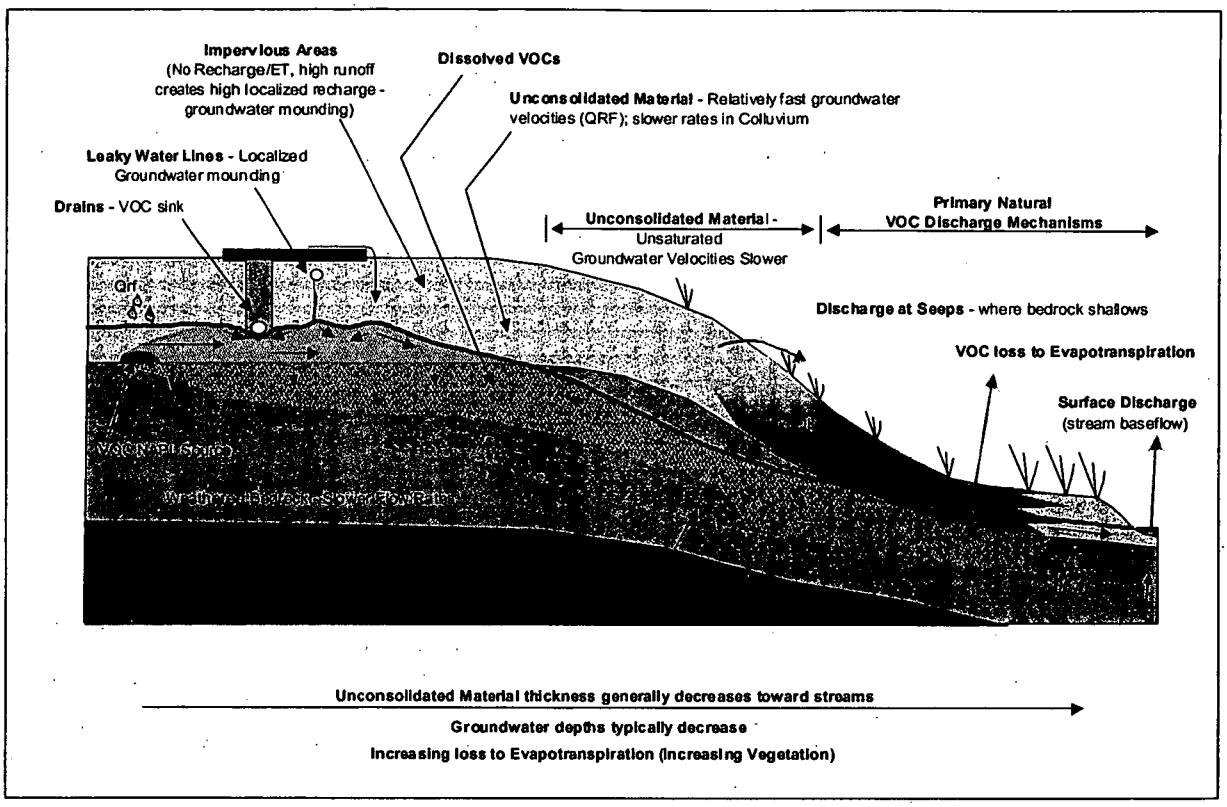

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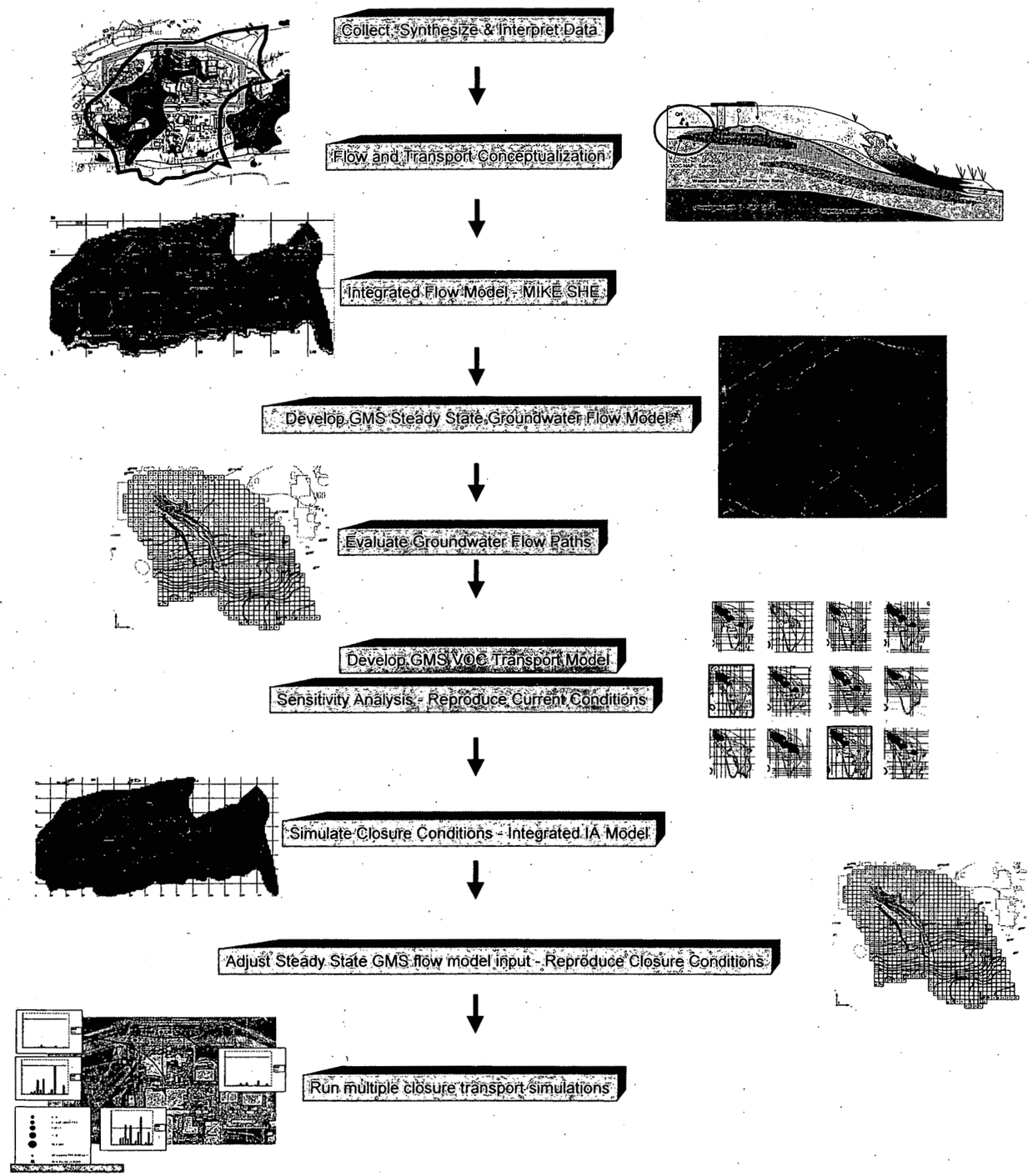
Figure 4-23. VOC Modeling Approach



- Geology
- Hydrology
- Chemical Data

- Saturated Zone Flow and Transport – important
- Local scale features important to transport
  - Bedrock surface
  - Hillslope structure
  - Utilities

- Calibrate key system parameters
- Simulate integrated flow conditions accurately

- Forms the basis for Reactive Transport Simulations - RT3D

- Confirm Source Locations
- Confirm Source Timing
- Confirm Pathways

- Identify key parameters affecting transport/fate
- Estimate range of key parameters reproduce observed trends
- Determine effective Source concentrations
- Determine appropriate source depths
- Confirm source locations

- Calculate closure condition heads and discharge

- Forms the basis for Reactive Transport Simulations - RT3D

PREDICT:
- range of Cmax in groundwater at surface discharge locations
- approximate extent of discharge locations

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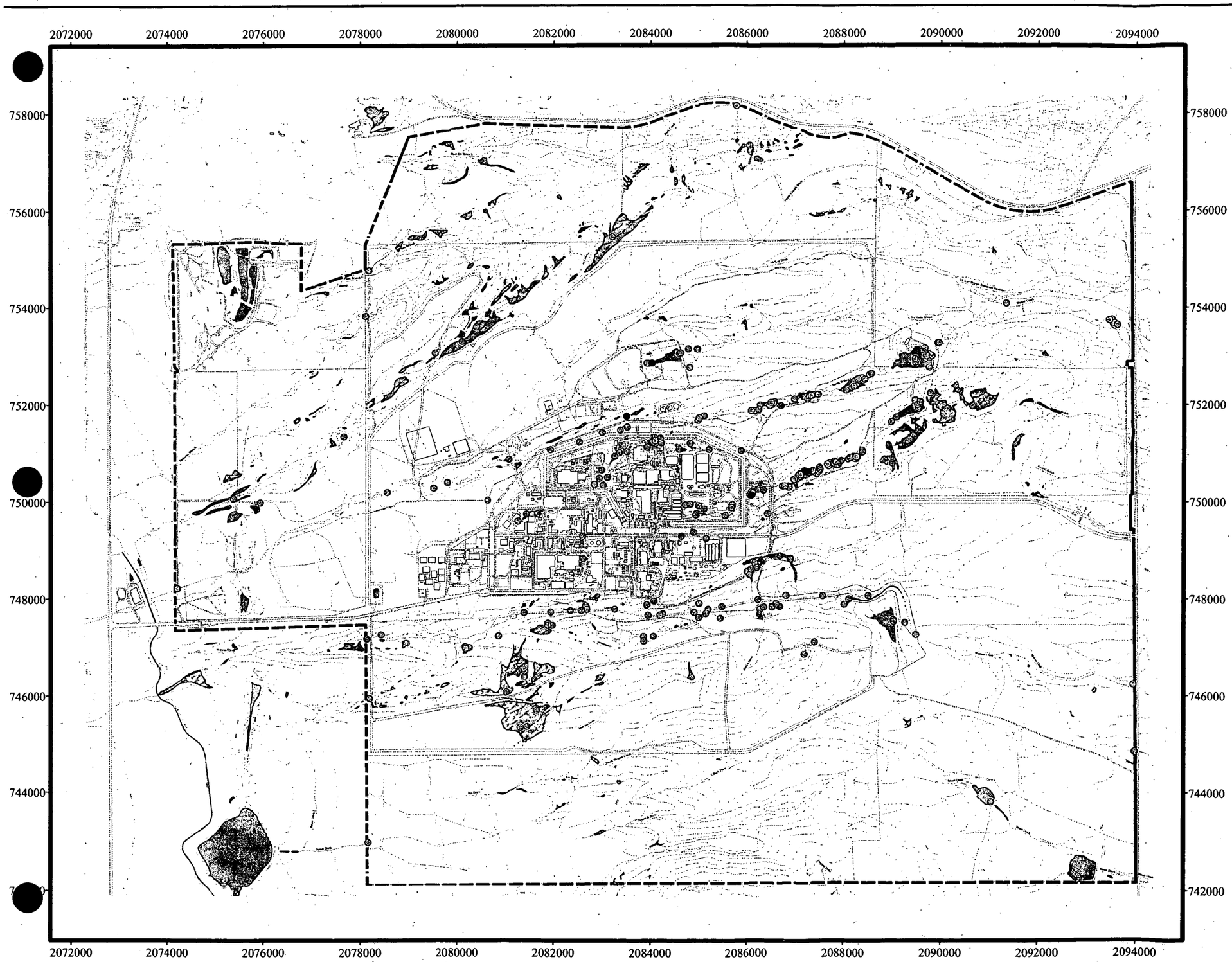

Figure 4-24
Surface Water - 1,1-Dichloroethene

Legend

- Constituent concentration > 10 x SWPRG (1,013,890 ug/L)
- Constituent concentration > SWPRG (101,389 ug/L) and < or = 10 x SWPRG (1,013,890 ug/L)
- Constituent concentration > surface water standard (7 ug/L) and < or = SWPRG (101,389 ug/L)
- Constituent concentration < or = surface water standard (7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 8/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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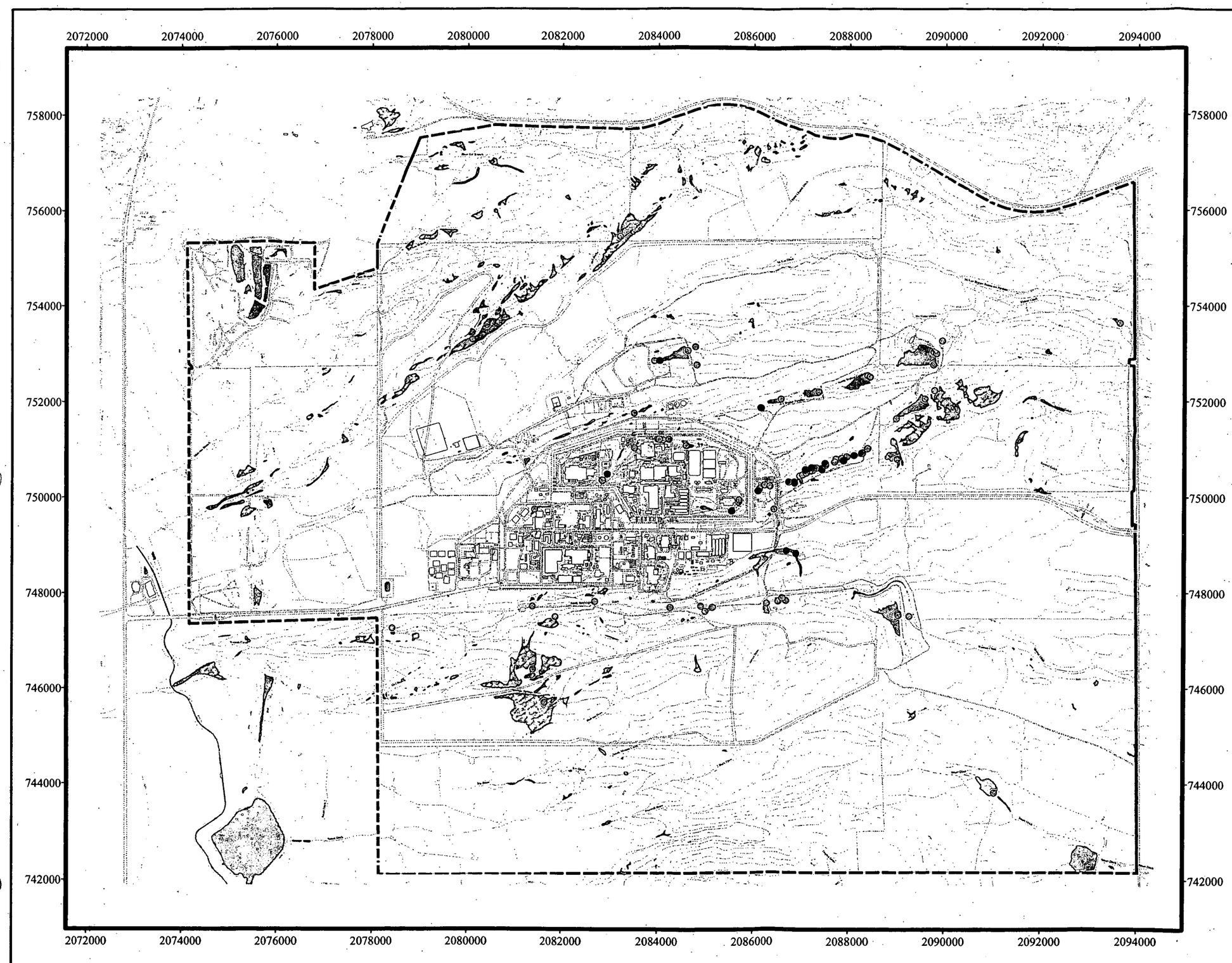

Figure 4-27
Surface Water - cis-1,2-Dichloroethene

Legend

- Constituent concentration > 10 x SWPRG (182,500 ug/L)
- Constituent concentration > SWPRG (18,250 ug/L)and < or = 10 x SWPRG (182,500 ug/L)
- Constituent concentration > surface water standard (70 ug/L) and < or = SWPRG (18,250 ug/L)
- Constituent concentration < or = surface water standard (70 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 8/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.

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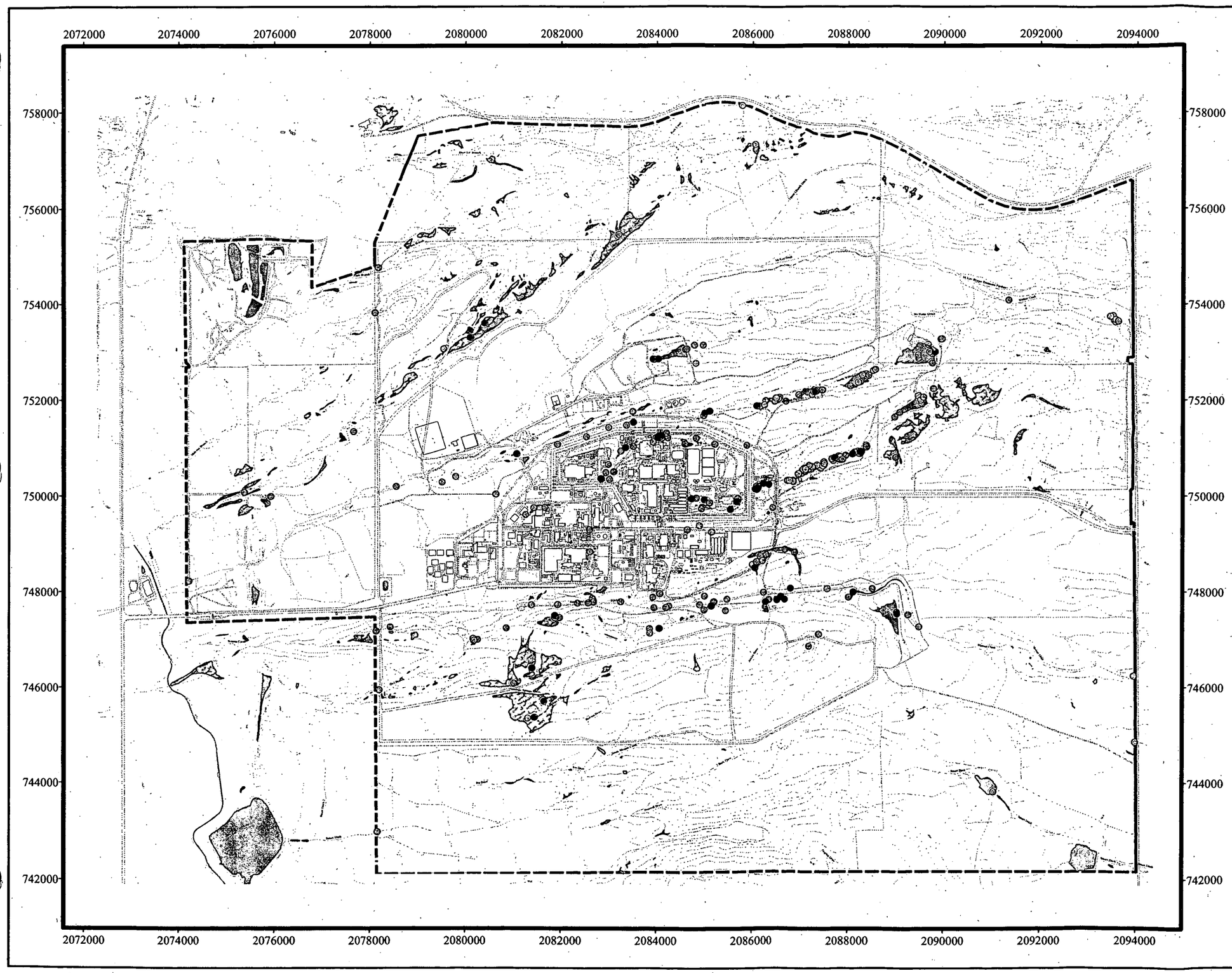

Figure 4-28
Surface Water - Methylene Chloride

Legend

- Constituent concentration > 10 x SWPRG (101,210 ug/L)
- Constituent concentration > SWPRG (10,121 ug/L) and < or = 10 x SWPRG (101,210 ug/L)
- Constituent concentration > surface water standard (4.7 ug/L) and < or = SWPRG (10,121 ug/L)
- Constituent concentration < or = surface water standard (4.7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 8/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.

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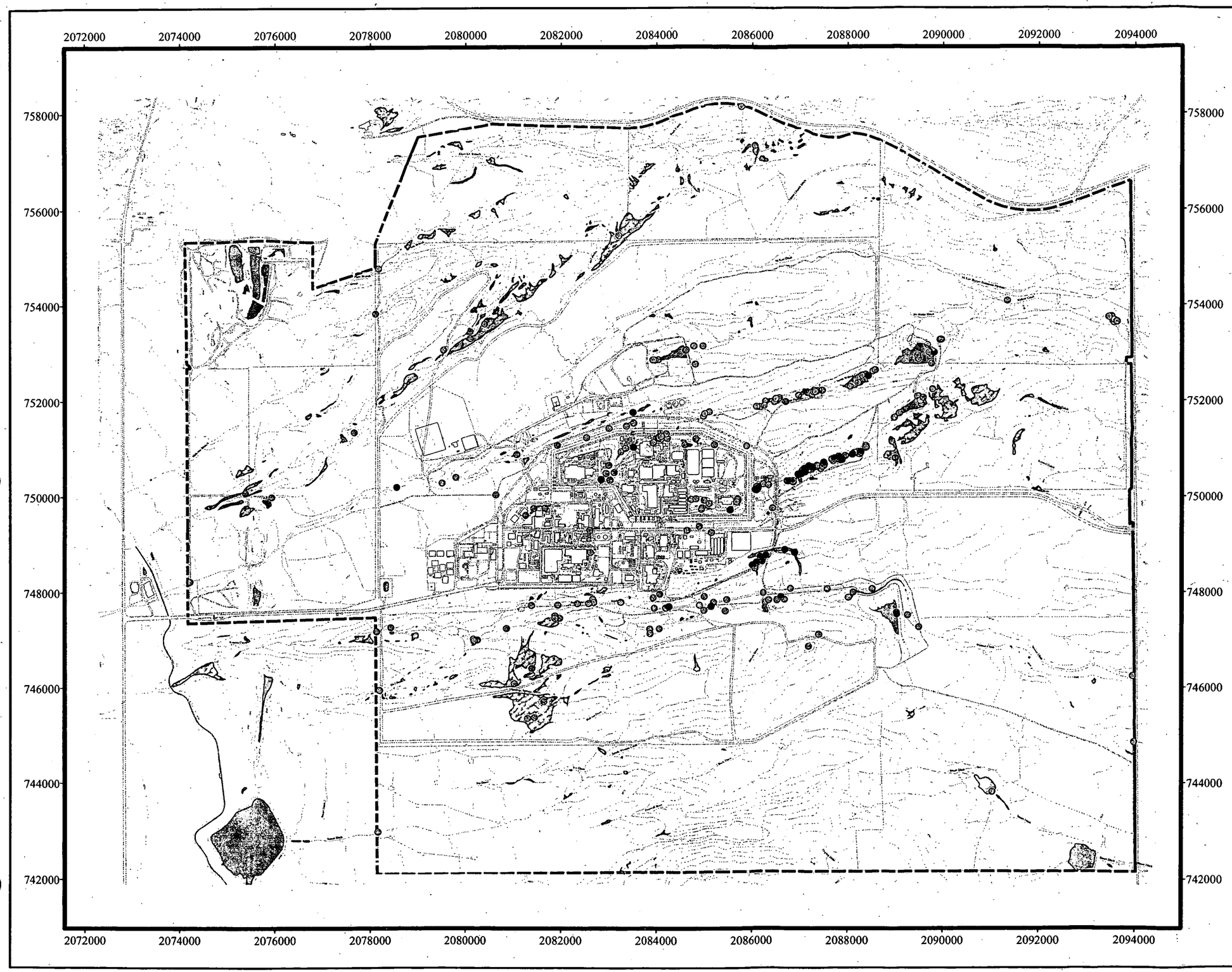

Figure 4-29
Surface Water - Tetrachloroethene

Legend

- Constituent concentration > 10 x SWPRG (1,406 ug/L)
- Constituent concentration > SWPRG (140.6 ug/L) and < or = 10 x SWPRG (1,406 ug/L)
- Constituent concentration > surface water PQL (1 ug/L) and < or = SWPRG (140.6 ug/L)
- Constituent concentration < or = surface water PQL (1 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 9/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.
- If the surface water standard is less than the practical quantitation limit (PQL); the PQL is referenced instead of the surface water standard.
- PCE surface water standard is 0.8 ug/L. PQL is 1 ug/L. Therefore map displays values > PQL.

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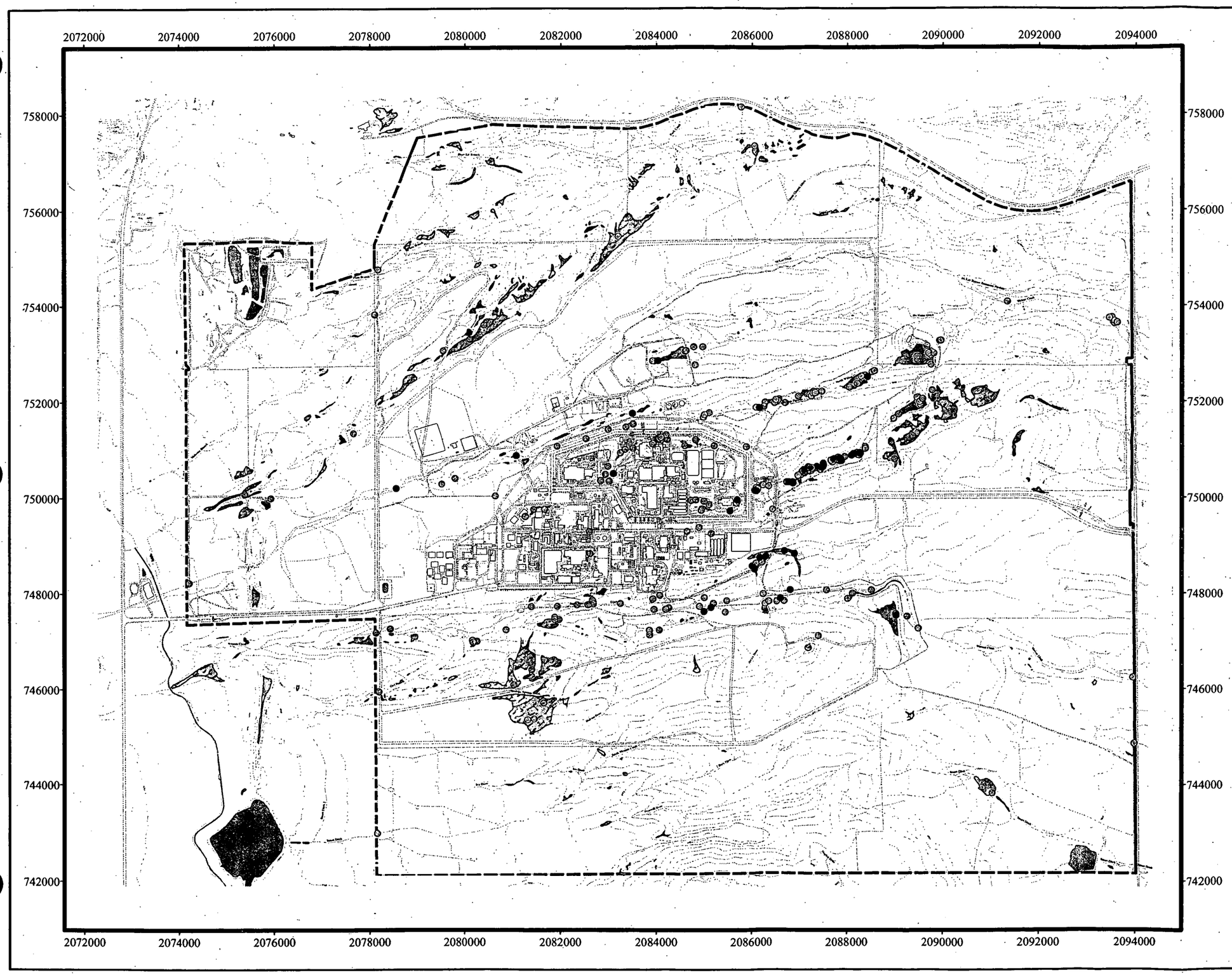

Figure 4-30
Surface Water - Trichloroethene

Legend

- Constituent concentration > 10 x SWPRG (1,898 ug/L)
- Constituent concentration > SWPRG (189.8 ug/L) and < or = 10 x SWPRG (1,898 ug/L)
- Constituent concentration > surface water standard (2.7 ug/L) and < or = SWPRG (189.8 ug/L)
- Constituent concentration < or = surface water standard (2.7 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 8/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: December 7, 2004

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Prepared for:

KAISER•HILL

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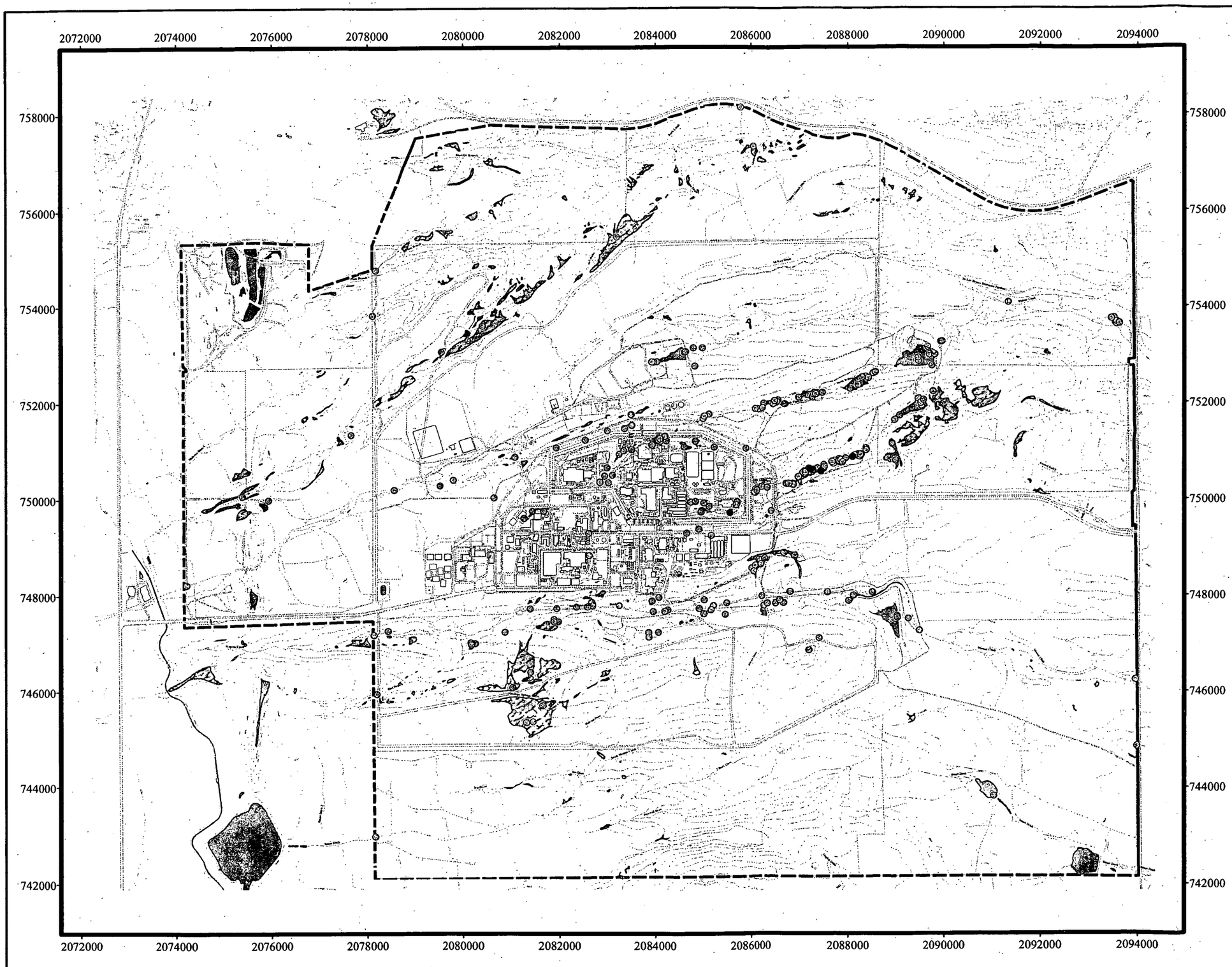

Figure 4-31
Surface Water - Vinyl Chloride

Legend

- Constituent concentration > 10 x SWPRG (506 ug/L)
- Constituent concentration > SWPRG (50.6 ug/L) and < or = 10 x SWPRG (506 ug/L)
- Constituent concentration > Surface Water Standard (2 ug/L) and < or = SWPRG (50.6 ug/L)
- Constituent concentration < or = Surface Water Standard (2 ug/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 8/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.

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1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
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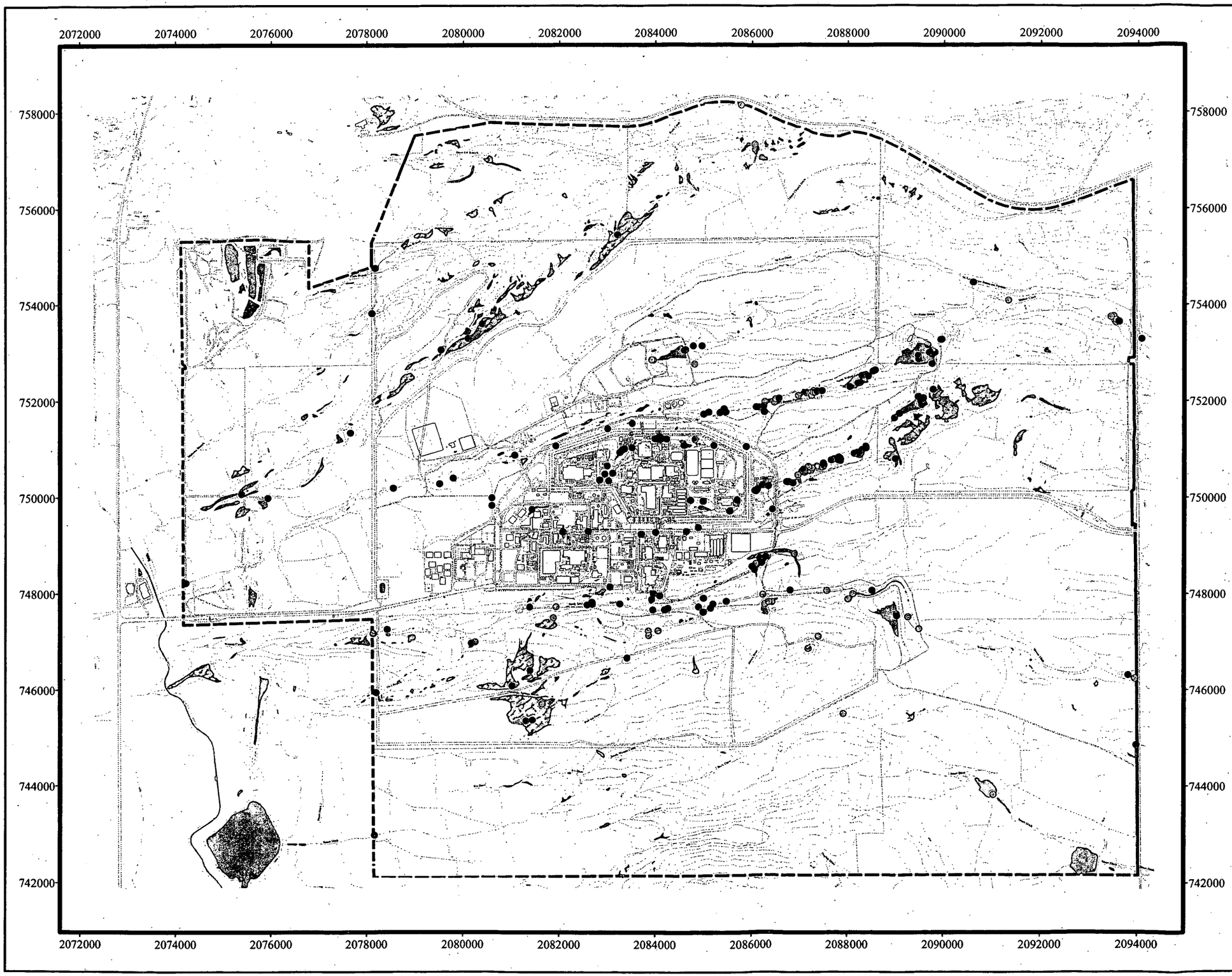

Figure 4-32
Surface Water - Nitrate/Nitrite

Legend

- Constituent concentration > 10 x SWPRG (32,444 mg/L)
- Constituent concentration > SWPRG (3,244 mg/L) and < or = 10 x SWPRG (32,444 mg/L)
- Constituent concentration > surface water PQL (10 mg/L) and < or = SWPRG (3,244 mg/L)
- Constituent concentration < or = surface water PQL (10 mg/L)
- Constituent not detected

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 9/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.
- If the surface water standard is less than the practical quantitation limit (PQL), the PQL is referenced instead of the surface water standard.

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Scale = 1 : 24,000
1 inch represents 2,000 feet

State Plane Coordinate Projection
Colorado Central Zone
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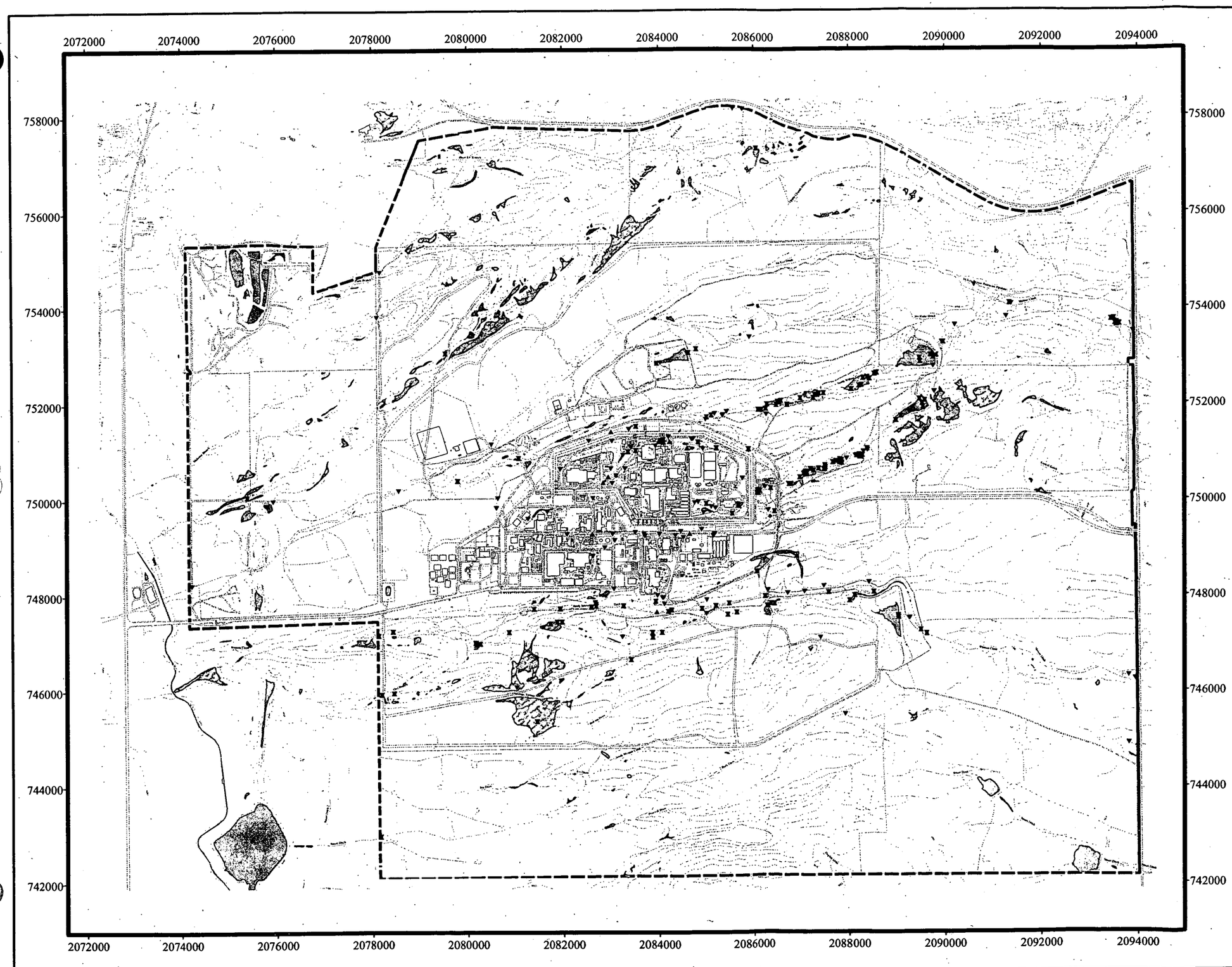

Figure 4-33
Surface Water - Total Isotopic Uranium

Legend

- Constituent concentration > 10 x SWPRG (41,729 pCi/L)
- Constituent concentration > SWPRG (4,172.9 pCi/L)and < or = 10 x SWPRG (41,729 pCi/L)
- Constituent concentration > surface water standard (10 pCi/L) and < or = SWPRG (4,172.9 pCi/L)
- Constituent concentration < or = surface water standard (10 pCi/L)
- Constituent not detected
- Filtered Uranium data
- Unfiltered Uranium data

Standard Map Features

- Existing or demolished building or structure
- Seep
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Site boundary
- Topographic contour (20-foot)

Notes:
- Data presented are the results from surface water samples collected from 6/28/91 through 8/31/04. At locations where more than one sample was collected, the most recent sample result is displayed on the figure.

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Scale = 1 : 24,000
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State Plane Coordinate Projection
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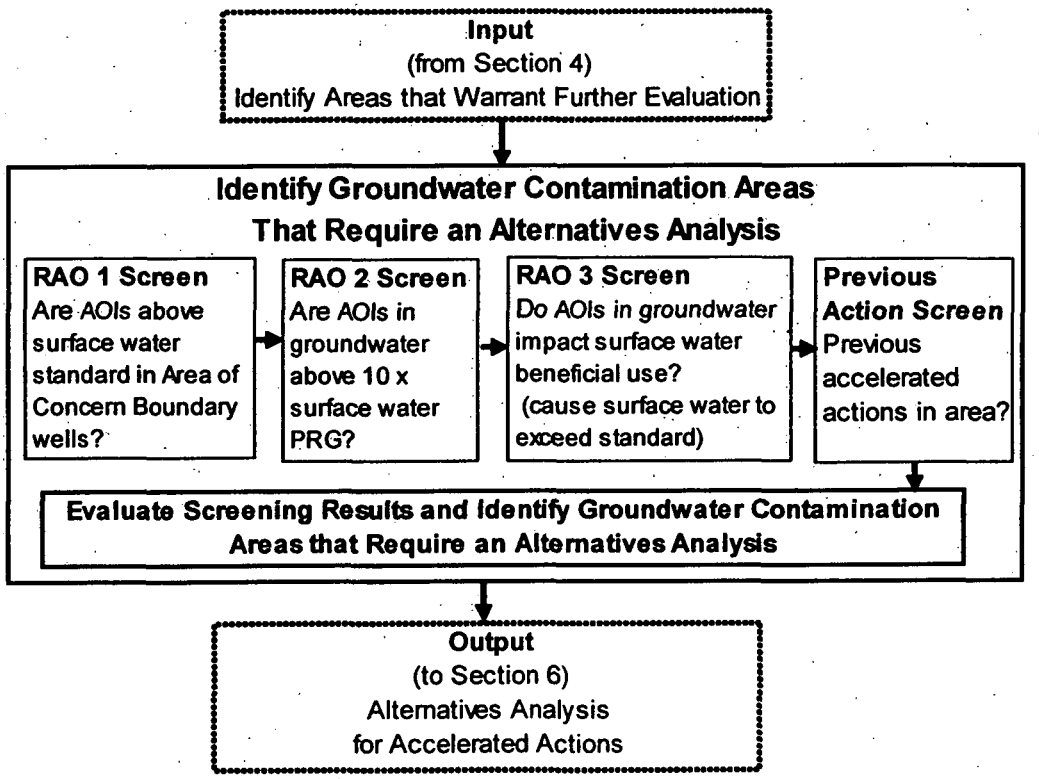
5.0 IDENTIFICATION OF GROUNDWATER CONTAMINANT PLUMES THAT REQUIRE AN ALTERNATIVES ANALYSIS

5.1 Description of the Evaluation Process

After AOIs have been identified (as presented in Section 3.0), and areas with groundwater contamination have been identified that warrant further evaluation (as presented in Section 4.0), additional screening steps are performed to determine the areas that require having an alternatives analysis for an accelerated remedial action. This evaluation process involves the major screening steps depicted on Flow Chart 5-1, summarized below, and presented in detail in subsequent sub-sections.

Flow Chart 5-1. Process to Identify Groundwater Contaminant Plumes That Require an Alternatives Analysis



RAO 1 Screening

Determine whether groundwater contaminants at the Area of Concern (AOC) boundary wells are detected above the surface water standards. If so, then determine which groundwater contaminant plumes(s) are contributing contamination that impacts the affected AOC boundary well.

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RAO 2 Screening

For each groundwater contaminant plume, determine whether it is located adjacent to surface water (e.g., streams, seeps, ponds). If so, does the concentration of any single groundwater AOI in that area exceed a risk of 1×10^{-5} for a WRW? A risk of 1×10^{-5} is defined in this document as having a contaminant concentration of 10 times the respective SWPRG for a WRW.

The contaminant concentration in each groundwater plume is based on the most recent groundwater data available from each well. In addition, results from computer model simulations of VOC transport are also taken into consideration. The model simulated integrated hydrologic processes, coupled with long-term simulations of VOC transport in groundwater.

RAO 3 Screening

For each groundwater contaminant plume, determine whether it is located adjacent to surface water (e.g., streams, seeps, or ponds). If so, does the contaminated groundwater discharged to surface water impact the beneficial use of surface water? The beneficial use of surface water is consistent with the surface water standards.

Previous Accelerated Action Screening

For each groundwater contaminant plume, determine whether a previous accelerated action mitigates the groundwater contamination in the area.

Evaluate Screening Results and Identify Areas That Require an Alternatives Analysis

Evaluate the screening results. Identify the groundwater contaminant plumes that may require an accelerated action, and therefore warrant having an alternatives analysis to select the appropriate action.

For each area selected, an alternatives analysis is performed to determine the appropriate accelerated action for that specific area. The alternatives analysis process is presented in Section 7.0. Proposed actions for each area are based on a range of reasonable and technically viable alternatives for groundwater remediation. Depending on the physical characteristics of the location and the nature of the groundwater contamination, viable alternatives can range from source removal to phytoremediation.

This overall evaluation process is presented in detail in the following sub-sections, and is diagrammed in detail in Appendix F. A summary of the results of this analysis, for each of the groundwater contamination areas evaluated, is provided in Section 5.7.

5.2 Groundwater Contaminant Plumes That Require Evaluation

As discussed in Section 0, 13 areas were identified to warrant evaluation as groundwater contaminant plumes that could potentially require an accelerated remedial action. The 13 areas, and the relevant groundwater AOIs in each, are listed in Table 5-1. Review of the

plume maps (Figure 4-12 through Figure 4-21), indicates overlap of the areal extent from one AOI plume to another.

Table 5-1. Groundwater Contaminant Plumes to be Evaluated

Groundwater Plume Area	Groundwater AOI(s)
Building 730 (IHSS 118.1)	CT, CF, PCE
East Trenches	CT, CF, PCE, TCE
Solar Evaporation Ponds	N, U
700 Area Northeast Plume	CT, CF, PCE, TCE, N, U
Mound (IHSS 113)	CF, PCE, TCE
Oil Burn Pit #2 (southeast of Building 991)	CF, PCE, TCE
903 Pad (IHSS 112)	CT, CF, PCE, TCE
Ryan's Pit (IHSS 109)	CT, CF, PCE, TCE, U
IHSS 119.1 (OU1)	PCE, TCE, U
Central IA	CT, CF, PCE, TCE, VC
PU&D Yard	PCE
Oil Burn Pit #1	TCE, VC
Building 444	CF, PCE, TCE

5.3 RAO 1 Screening

5.3.1 RAO 1 Screening Process

RAO 1 is to "Meet groundwater quality standards, which are the surface water ALs and standards in ALF Table 1, at AOC boundary wells."

RAO 1 Screening Assumptions:

- Since RAO 1, as defined in the Groundwater and Soil RAOs Tech Memo currently being drafted, does not specify what the AOC boundary wells are, their locations must be assumed to perform this screening analysis. It is assumed there will be seven AOC boundary wells. The locations of six of the wells are shown on Figure 5-1. The location of the seventh well is undetermined, though it is anticipated to be in the Woman Creek drainage, upstream from Pond C-1, near the location of well 5587 (Figure 5-1). Therefore, sample results from well 5587 are used to evaluate groundwater quality for the new AOC well.
- The most recent data available for each well are used for the screening evaluation. More than 85 percent of the data used in the evaluation were collected in the past 10 years.

Determining whether RAO 1 is achieved is a two-part process, as described below:

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1. Each AOC boundary well is evaluated to determine whether any groundwater AOIs are detected at a concentration above their respective surface water standard (see Figure 5-1). If the AOC boundary wells pass this screen (i.e., meaning the most recent sample results for each AOI, at each well, are below the corresponding surface water standards for each contaminant), then RAO 1 is met, and further evaluation is not required. However, if any of the AOC boundary wells do not meet this screen, then the evaluation process continues to the next step;

2. Further analysis is performed to determine which groundwater contaminant plume(s), as identified in Section 5.2, caused the elevated AOI concentration at the AOC boundary well. For uranium, results are compared with ICP/MS sample results to determine whether the elevated activity is associated with natural or anthropogenic uranium (see Appendix B).

5.3.2 RAO 1 Screening Results

To determine whether RAO 1 is met, sample results for each groundwater AOI, at each AOC well, are compared with the corresponding surface water standard. The most recent sample results at the AOC boundary wells, for each AOI, are shown in Table 5-2.

Table 5-2. RAO 1 Screening Summary

AOI	Surface Water Standard[1]	Units	AOC Boundary Wells[2]						
			20798	10594	00997	11104	6886	10304	5587[3]
1,1-DCE	7	µg/L	1U	1U	1U	1U	1U	1U	1U
CT	1	µg/L	1U	1U	1U	1U	1U	1U	1U
CF	5.7	µg/L	1U	1U	1U	1U	1U	1U	1U
cis-1,2-DCE	70	µg/L	1U	1U	1U	1U	1U	1U	1U
MC	4.7	µg/L	1U	1U	1U	1U	1U	1U	1U
PCE	1	µg/L	1U	1U	1U	1U	1U	1U	1U
TCE	2.7	µg/L	1U	1U	1U	1U	1U	1U	1U
VC	2	µg/L	1U	1U	1U	1U	1U	1U	1U
Nitrate	10,000	µg/L	20U	48	340	-	10U	10U	2,400
Uranium	10 (Walnut Ck) 11 (Woman Ck)	pCi/L	-	43.73 (see note 4)	-	-	-	-	10.04 (see note 5)
		Meet RAO?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[1]Surface water standard or Practical Quantitation Limit (PQL), whichever is higher.
[2]Laboratory qualifiers: U - undetect; J - estimated value
[3] Well 5587 is approximately 100 feet from the location of an AOC well to be constructed on Woman Creek southeast of Building 881.
[4]Although the total uranium concentration at well 10594 is above the surface water uranium standard of 10 pCi/L, the uranium in well 10594 has an isotopic uranium signature associated with natural uranium (see Appendix B). Therefore, for uranium, well 10594 does not fail the RAO1 screen.
[5]Well 5587 is located in the Woman Creek drainage basin, which has a surface water uranium standard of 11 pCi/L. Therefore, the uranium concentration in well 5587 is below the surface water standard for Woman Creek.

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These results, where available at the known AOC boundary wells, are equal to or below the respective surface water standards, with one exception. The uranium result at well 10594 on North Walnut Creek, 43.73 pCi/L, is higher than the Walnut Creek surface water standard of 10 pCi/L. However, the uranium in well 10594 has an isotopic uranium signature associated with natural uranium (see Appendix D). Therefore, this well was determined to meet the RAO 1 screen.

5.4 RAO 2 Screening

5.4.1 RAO 2 Screening Process

RAO 2 is "Groundwater that exits at seeps must achieve $1x10^{-5}$ risk and Hazard Index of 1 or less to WRW and not pose significant risk of adverse ecological effects."

RAO 2 Screening Assumptions:

- Seeps are defined as any location where groundwater discharges to the surface, regardless of the discharge rate, and correspond with the 1995 seep coverage (EG&G, 1995b).
- "Adjacent to surface water" is defined as any part of the groundwater contaminant plume that comes into contact with a defined surface water channel. All surface water channels are considered, regardless if they have ephemeral or continual flow.
- It is assumed that the AOI concentration for each groundwater contaminant plume is based on each well in the plume meeting the 1×10^{-5} risk value. Using any other selection criteria for which wells to evaluate, such as only those wells within a certain distance from the stream channel, was determined to be arbitrary. Variables such as hydraulic gradient, hydraulic conductivity, and solubility of the AOI all play a role in the potential for groundwater AOIs to impact surface water. Therefore, each well in each area plume was included in the analysis.
- For the evaluation of model data, the AOI concentration is based on the concentration estimated at a surface water discharge area, not the concentration in the PSA center. This assumption allows for the consideration of processes such as natural attenuation, volatilization, and ET effects, now and in the future.

Determining whether RAO 2 is achieved is a two-part process, as described below:

- Each groundwater contaminant plume is evaluated to determine whether it contains a groundwater seep or is adjacent to surface water (e.g., channel or pond). If the groundwater contamination is not collocated with a seep or adjacent to surface water, then that specific contamination area achieves RAO 2, and further evaluation is not required. However, if a groundwater contaminant plume is either collocated with a seep or adjacent to surface water, then that area must be further evaluated to assess the quality of the groundwater, as described in the next step;

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- To evaluate the quality of the groundwater for RAO 2, the groundwater is assessed in terms of the water quality achieving a 1×10^{-5} risk and an Hazard Index of 1 or less to a WRW (see Section 1.6 for a discussion on how the risk values were derived). The SWPRGs are calculated based on a 1×10^{-6} risk of increased cancer. In order to be consistent with risk-based soil cleanup levels, a 1×10^{-5} risk groundwater quality screen for RAO 2 was applied. This AOI concentration is 10 times higher than the SWPRG values. Therefore, to meet RAO 2 (in plumes that are collocated with a seep or adjacent to surface water as described in the step above), the concentration of each AOI in a groundwater contamination area must be equal to or below 10 times the respective SWPRG based on measured data and model estimates.

The component of RAO 2 that addresses adverse ecological effects is not discussed in this IM/IRA. Ecological effects and potential remedial actions associated with such effects will be addressed in a separate document.

5.4.2 RAO 2 Screening Results

5.4.2.1 Screening Based on Measured Data

To assess whether RAO 2 is met, screening steps were applied in two phases. First, all of the groundwater contaminant plumes were overlaid on a map of the Site (see Figure 4-12 through Figure 4-21). Second, to evaluate individual groundwater contamination areas, individual wells were identified if any of the AOIs had measured concentrations, based on the most recent sampling of the well, greater than or equal to 10 times the respective SWPRG. The results of the RAO 2 screen are summarized in Table 5-3.

Table 5-3. RAO 2 Screening Summary – Based on Measured Data in Plumes

Groundwater Contaminant Plume Screening[1] Question	Groundwater Contaminant Plume												
	CT Plume (IHSS 118.1)	East Trenches	SEPs	700 Area NE	Mound Site	Oil Burn Pit #2	903 Pad	Ryan's Pit	OU1 (IHSS 119.1)	IA Plume	PU&D Yard	Oil Burn Pit #1	Building 444
Plume collocated with a seep?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Plume adjacent to surface water?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Groundwater contaminants > 10 x SWPRGs? (anywhere in plume)	Yes CT	Yes PCE TCE	No	Yes TCE N	Yes PCE TCE	Yes PCE TCE	Yes PCE CT	Yes PCE TCE	Yes PCE TCE	No	Yes PCE	Yes VC	No
Meet RAO 2?[1]	No	No	Yes	No	No	No	No	No	No	Yes	No	Yes	Yes

[1]A groundwater contamination area meets RAO 2 if there is a "no" answer for both of the first two screening questions, and/or a "no" answer for the last screening question.

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5.4.2.2 Screening Based On Model Simulation

While measured data serve as the primary basis for determining whether RAO 2 is achieved, model results of the future land configuration are also considered. However, evaluation of the model results is somewhat different than the evaluation of the measured results. Whereas the measured data are compared with the 1 x 10^{-5} risk screen for any location within each groundwater contaminant plume, the modeled data are compared with the 1 x 10^{-5} risk screen at the point where the groundwater discharges to surface water from each contaminant plume.

The model simulations reflect the proposed IA land reconfiguration. The estimated concentration of each AOI at a surface discharge area is simulated for long time periods (hundreds of years in some cases) (K-H, 2004f). Results of the RAO 2 screening, based on model results, are summarized in Table 5-4. Note that the screening based on these model results varies from the screening based on the measured data, because the model result is for areas where groundwater discharges to the surface. The measured data, in contrast, are from wells in the groundwater contaminant plumes, but not necessarily at locations where the groundwater discharges to the surface.

Table 5-4. RAO 2 Screening Summary – Based on Model Results at Surface Discharge Areas

Groundwater Contaminant Plume Screening Question	Groundwater Contaminant Plume												
	CT Plume (IHSS 118.1)	East Trenches	SEP	700 Area NE	Mound Site	Oil Burn Pit #2	903 Pad	Ryan's Pit	OU (IHSS 119.1)	IA Plume	PU&D Yard	Oil Burn Pit #1	Building 444
Plume collocated with a seep?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Plume adjacent to surface water?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Groundwater contaminants > 10 x SW PRGs? (future discharge to surface)	No	Yes TCE	No	No	No	No	No	Yes PCE TCE	No	No	No	No	No
Meets RAO 2?	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes

5.5 RAO 3 Screening

5.5.1 RAO 3 Screening Process

RAO 3 is to "Restore contaminated groundwater that discharges to surface seeps or directly to surface water as baseflow, and that is a significant source of surface water, to

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its beneficial use of surface water protection wherever practicable in a reasonable timeframe."

RAO 3 Screening Assumptions:

- Seeps are defined as any location where groundwater discharges to the surface, regardless of the discharge rate, and correspond with the 1995 seep coverage (EG&G, 1995b).
- "Adjacent to surface water" is defined as any part of the groundwater contaminant plume coming in contact with a defined surface water channel. All surface water channels are considered, regardless of whether they are ephemeral or perennial.
- The evaluation can be performed using the available surface water data for the groundwater AOIs.

Determining whether RAO 3 is achieved is a two-part process, as described below:

1. Similar to the RAO 2 screening process, each groundwater contaminant plume is evaluated to determine whether it contains a groundwater seep, or is adjacent to surface water (e.g., channel or pond). If neither case is true, then that specific contamination area achieves RAO 3, and further evaluation is not required. However, if a groundwater contamination area is either collocated with a seep or adjacent to surface water, then that area must be further evaluated to assess the quality of the groundwater, as discussed below.
2. To evaluate the impact of groundwater on the beneficial use of surface water, surface water quality is evaluated in seeps or channels located downgradient from each of the groundwater contamination areas. Because achieving "beneficial use" means surface water quality must achieve the surface water standards to meet RAO 3, groundwater contamination cannot impact surface water quality to the point where surface water standards are not met. To assess whether RAO 3 is met, surface water quality in seeps or channels downstream from the groundwater contaminant plumes is evaluated, using the most recently collected surface water quality data as well as model estimates of future groundwater quality at the surface discharge areas. If the AOIs in surface water meet the surface water standards, then RAO 3 is achieved. Otherwise, RAO 3 is not met.

5.5.2 RAO 3 Screening Results

5.5.2.1 Screening Based on Measured Data

To assess whether RAO 3 is met, screening steps were applied in two phases. First, all of the groundwater contaminant plumes were overlaid on a map of the Site (see Figure 4-12 through Figure 4-21). Second, surface water sample results that exceed the surface water standard (see Figure 4-24 through Figure 4-33) were reviewed with respect to the groundwater contamination areas. A summary of the RAO 3 screening results, based on the most recently collected surface water sample data, is presented in Table 5-5.

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Table 5-5. RAO 3 Screening Summary – Based on Measured Data

Groundwater Contaminant Plume Screening Question	Groundwater Contaminant Plume												
	CT Plume (IHSS 118.1)	East Trenches	SEPs	700 Area NE	Mound Site	Oil Burn Pit #2	903 Pad	Ryan's Pit	OU1 (IHSS 119.1)	IA Plume	PU&D Yard	Oil Burn Pit #1	Building 444
Plume co-located with a seep?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Plume adjacent to surface water?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does plume impact surface water beneficial use? (above sw standard)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Meet RAO 3?	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	Yes

5.5.2.2 Screening Based On Model Simulations

Similar to RAO 2, measured data serve as the primary basis for determining whether RAO 3 is achieved. However, model results of the proposed land configuration are also taken into consideration. While the measured data are from surface water samples collected from channels or seeps, the modeled data represent groundwater quality at surface discharge areas, from each groundwater PSA, and therefore may differ somewhat from the screening based on measured data. Results of the RAO 3 screening, based on model results, are summarized in Table 5-6.

Table 5-6. RAO 3 Screening Summary – Based on Model Results

Groundwater Contaminant Plume Screening Question	Groundwater Contaminant Plume												
	CT Plume (IHSS 118.1)	East Trenches	SEPs	700 Area NE	Mound Site	Oil Burn Pit #2	903 Pad	Ryan's Pit	OU1 (IHSS 119.1)	IA Plume	PU&D Yard	Oil Burn Pit #1	Building 444
Plume collocated with a seep?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Plume adjacent to surface water?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does plume impact s. water beneficial use? (at discharge)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
Meet RAO 3?	No	No	No	Yes	No	No	No	No	Yes	No	No	Yes	Yes

5.6 Previous Accelerated Action Screening

Section 4.6 provides a description of remedial actions that have previously been performed that are likely to provide a significant beneficial impact on groundwater quality. This step puts those previous actions into the screen so they can be considered when determining which areas warrant further evaluation. The results of the previous accelerated action screening are summarized in Table 5-7.

Table 5-7. Groundwater Contaminant Plumes and Previous Accelerated Actions

Accelerated Action Previously Performed	Groundwater Contaminant Plume												
	CT Plume (IHSS 118.1)	East Trenches	SEPs	700 Area N.E.	Mound Site	Oil Burn Pit #2	903 Pad	Ryan's Pit	OU1 (IHSS 119.1)	IA Plume	PU&D Yard	Oil Burn Pit #1	Building 444
Soil removal	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	No	No
In-situ soil treatment	No	No	No	No	No	No	No	No	No	No	Yes	No	No
Groundwater collection and treatment	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes (see note 1)	No	No	No	No

[1]The groundwater collection and treatment system for OU1 was decommissioned in accordance with the OU1 CAD/ROD (DOE, 2001a)

5.7 Evaluate Screening Results

The evaluation process involves compiling and reviewing the results of the five preceding screening steps. Based on the results of the analysis, determination is made regarding which of the 13 groundwater contaminant plumes, identified in Section 5.2, should be selected to have an alternatives analysis performed for a potential accelerated action. The summary of screening results is compiled in Table 5-8. Based on the analysis of screening results, 7 out of the 13 groundwater contaminant plumes are recommended to have an alternatives analysis performed. These include:

- Carbon Tetrachloride Plume (IHSS 118.1)
- East Trenches (IHSS Group 900-12);
- SEPs (IHSS 101);
- Mound Site (IHSS 113);
- Oil Burn Pit #2 (IHSS 153);
- 903 Pad (IHSS 112); and
- Ryan's Pit (IHSS 109).

Table 5-8. Summary of Screening Process Results to Determine Need for An Alternatives Analysis, For Each Groundwater Contamination Area

Process Main Step	Process Sub-Step	Groundwater Contamination Areas												
Identify Groundwater Contamination Areas	**Define Groundwater Contam. Plumes** (Areas with groundwater AOIs and contiguous groundwater plumes)	**Carbon Tetrachl. Plume (IHSS 118.1)**	**East Trenches (IHSS Group 900-12)**	**SEPs (IHSS 101)**	**700 Area Northeast Plume**	**Mound (IHSS 113)**	**Oil Burn Pit #2 (IHSS 153)**	**903 Pad (IHSS 112)**	**Ryan's Pit (IHSS 109)**	**OU1 (IHSS 119.1)**	**IA Plume (Multiple co-mingled sources)**	**PU&D Yard (IHSS 170)**	**Oil Burn Pit #1 (IHSS 128)**	**Building 444**
	List individual AOIs in each area (AOIs detected in groundwater in each plume)	CT MC CF PCE	1,1-DCE PCE TCE CT CF	N, U	CT, CF PCE TCE N, U	PCE TCE CF	PCE TCE CF	cis-1,2-DCE PCE TCE 1,1-DCE CT, CF N, U	PCE TCE CT CF, U	PCE TCE N, U	cis-1,2-DCE PCE TCE 1,1-DCE CT, CF VC	PCE	cis-1,2-DCE TCE VC	PCE TCE CF
RAO 1 Screen	**At the AOC boundary wells, are any groundwater contaminants detected above surface water standards?** (Based on current data)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)	No (Meets RAO 1)
RAO 2 Screen	**Is groundwater contamination area adjacent to surface water?** (e.g., streams, seeps, ponds)	Yes (ephemeral stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (seep, intermittent ditch)	Yes (perennial stream)	Yes (perennial stream)	Yes (seep, perennial stream)	Yes (perennial stream)	Yes (ephemeral stream)	Yes (seep, perennial stream)
	Groundwater greater than $1x10^{-5}$ risk? (Basis - Measured Data - wells in plume)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	No (Meets RAO 2)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	No (Meets RAO 2)	Yes (Does not meet RAO 2)	Yes (Does not meet RAO 2)	No (Meets RAO 2)
	Groundwater greater than $1x10^{-5}$ risk? (Basis - Model Data - estimate of groundwater quality in future discharges to surface water)	No (Meets RAO 2)	Yes (Does not meet RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	Yes (Does not meet RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)	No (Meets RAO 2)
RAO 3 Screen	**Is groundwater contamination area adjacent to surface water?** (e.g., streams, seeps, ponds)	Yes (ephemeral stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (perennial stream)	Yes (seep, intermittent ditch)	Yes (perennial stream)	Yes (perennial stream)	Yes (seep, perennial stream)	Yes (perennial stream)	Yes (ephemeral stream)	Yes (seep, perennial stream)
	Does groundwater cause impact to surface water beneficial use? (Basis - Measured Data - surface water samples)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	No (Meets RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	No (Meets RAO 3)	No (Meets RAO 3)	No (Meets RAO 3)
	Does groundwater cause impact to surface water beneficial use? (Basis - Model Data - estimate of groundwater quality in future discharges to surface water)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	No (Meets RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	No (Meets RAO 3)	Yes (Does not meet RAO 3)	Yes (Does not meet RAO 3)	No (Meets RAO 3)	No (Meets RAO 3)
Previous Action Screening	Subsurface soil removal action Completed for this area?	No	Yes (1996)	Yes, sludge removal (1994-1995).	No	Yes (1997)	No	Yes (2003)	Yes (1996)	No, no residual soil source found	Yes, several soil source removals completed.	No	No, no residual soil source found.	No
	Subsurface soil/source treatment action Completed for this area?	No	No	No	No	No	No	No	No	No	No	Yes (2003)	No	No
	Groundwater treatment system Completed for this area?	No	Yes (1999)	Yes (1999)	Yes (1999)	Yes (1998)	Yes (1998)	No	No	Yes (1992)	No	No	No	No
Evaluate Screening Results	**Evaluate screening results, area-by-area** - Examine areas that did not meet specific RAOs - Assess potential near-term and long-term impacts to surface water from groundwater contamination - Consider effectiveness of existing remedial actions	Soil source removal action, soil treatment planned for 2004	PCE, TCE detected detected above 1×10^{-5} risk. Also above surface water standard in South Walnut Creek.	Nitrate in North Walnut Creek above surface water standard.	No impact to sw currently detected. Modeling predicts no impact above surface water stds.	PCE, TCE detected above 1×10^{-5} risk	PCE, TCE detected above 1×10^{-5} risk	CT, PCE detected above 1×10^{-5} risk. Previous soil action was for rads.	TCE, PCE detected above 1×10^{-5} risk.	1992 gw treatment system decommissioned and no longer needed (per OU1 CAD/ROD). Modeling predicts no impact above sw stds.	Diffuse sources. Long distance from sources to surface water discharge. Multiple soil source removal accelerated actions performed.	Long distance from source to surface water. No observed impacts to surface water. Prior action implemented.	Long distance from source to surface water discharge; no discharge to surface water greater than the surface water standards	Long distance from source to surface water discharge; modeling predicts no discharge to surface water greater than the surface water standards
	Accel. Action Altern. Analysis Necessary?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No

The basis for where to conduct an alternatives analysis is summarized for each of the groundwater contaminant plumes in Table 5-9.

Table 5-9. Summary of Decision to Perform an Alternatives Analysis, by Groundwater Contaminant Plume

Groundwater Contaminant Plume	Recommend Performing Alternatives Analysis?	Basis of Decision
East Trenches	Yes	RAO 2 - PCE detected in groundwater adjacent to S. Walnut Creek at more than 10 x SWPRG. RAO 3 – Impact to surface water - based on PCE and TCE detected above SWPRG in s. Walnut Creek. Multiple other AOIs detected above surface water standard. Previous action – Soil removal action and groundwater collection and treatment system. However, elevated levels of VOCs currently observed in S. Walnut Creek.
Solar Ponds	Yes	RAO 3 – Impact to surface water - based on nitrate detected in groundwater above SWPRG. Previous action – Soil/sludge removal action and groundwater collection and treatment system. However, elevated nitrate currently observed in surface water in N. Walnut Creek.
Mound	Yes	RAO 2 – TCE and PCE detected in groundwater at more than 10 x SWPRGs. RAO 3 – Impact to surface water - based on TCE, PCE, CT detected above surface water standards. Model estimate also indicates TCE, PCE in surface water above standard in future. Previous action – Soil removal action and groundwater collection and treatment system. However, elevated VOCs currently observed in S. Walnut Creek.
Oil Burn Pit #2	Yes	RAO 2 – TCE and PCE detected in groundwater at more than 10 x SWPRG. RAO 3 – Impact to surface water - based on TCE, PCE, CT detected above surface water standard. Model estimate also indicates TCE, PCE in surface water above standard in future. Previous action – Groundwater collection and treatment system (Mound system) for portion of contamination. However, elevated VOCs currently observed in S. Walnut Creek.
903 Pad	Yes	RAO 2 – CT and PCE detected in groundwater at more than 10 x SWPRG. RAO 3 – Impact to surface water - based on CT and PCE detected above surface water standard in seep downstream. Model estimate also indicates all VOCs above surface water standard in future (though extent of contamination is climatically influenced - it is often unsaturated along hillslope). Previous action – Previous soil removal action, but targeted rads. Requires further characterization to determine whether soil removal action is warranted.

(table continued)

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Table 5-9 (continued)

Groundwater Contamination Area	Recommend Performing Alternatives Analysis?	Basis of Decision
Ryan's Pit	Yes	RAO 2 – TCE and PCE detected in groundwater at more than 10 x SWPRG. RAO 3 – Impact to surface water - TCE detected in surface water above SWPRG. Model estimate also indicates all VOCs above surface water standard in future (though extent of contamination is climatically influenced - it is often unsaturated along hillslope). Previous action – Previous soil removal action. However, elevated VOCs currently observed in wells.
Carbon Tetrachloride Plume (IHSS 118.1)	Yes	RAO 2 – CT detected in multiple wells above 10 x SWPRG. RAO 3 – CT detected downstream; supported by model results. Previous actions – Soil removal planned.
700 Area Northeast	No	RAO 2 – TCE, nitrate above 10 x SWPRG in wells. However, modeling does not indicate discharges to surface water in the future will be above 10 x SWPRGs. RAO 3 - No action necessary based on RAO 3 (no observed impacts to surface water quality per standards), though modeling of future discharges to surface does indicate CT above surface water standard (but below SWPRG). Previous action – Solar Ponds collection and treatment system (may capture all or portion of 700 Area Northeast plume)
OU1 (IHSS 119.1)	No	RAO 2 – Historic PCE, TCE above 10 x SWPRG in well. However, see reference below to previous action RAO 3 - Model estimate indicates no future impact to surface water for any VOCs relative to surface water standard. Previous action – Groundwater collection and treatment system previously used. Discontinued operation in accordance with OU1 CAD/ROD. No further collection and treatment necessary because contaminant migration appears limited in weathered bedrock.
IA Plume	No	RAO 2 – No action necessary based on RAO 2. RAO 3 – One location with TCE detected above surface water standard. No AOIs detected above SWPRGs. Previous action – None. Action difficult due to multiple diffuse sources.

(Table continued)

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Table 5-9 (continued)

Groundwater Contamination Area	Recommend Performing Alternatives Analysis?	Basis of Decision
PU&D Yard	No	RAO 2 – TCE above 10 x SWPRG at one well; long distance to discharge to surface water. RAO 3 – Meets RAO 3 for measured data. Surface water downstream from PU&D yard (west of where drainage from north [between 317 and 771] joins N. Walnut Creek) does not indicate impact from groundwater contaminants. Previous action – Soil treatment action using HRC.
Oil Burn Pit # 1	No	RAO 2 – VC above 10 x SWPRG at one well - does not discharge to surface water. RAO 3 – Meets RAO 3. Impacts to surface water not observed. Previous action – None. Natural biodegradation appears effective (K-H, 2004c).
Building 444	No	RAO 2 – Meets RAO 2. No action necessary based on RAO 2. RAO 3 – Meets RAO 3. Impacts to surface water not observed. Previous action – None.

Note that the plumes overlap in several of these areas. Therefore, in some cases, an accelerated action can simultaneously address more than one of the areas identified in Table 5-9 that warrants an alternatives analysis. Therefore, in Section 6.0, the alternatives address groundwater plumes in the following five plume areas:

- Carbon Tetrachloride Plume (IHSS 118.1)
- East Trenches (IHSS Group 900-12);
- SEPs (IHSS 101);
- Mound Site (IHSS 113)/Oil Burn Pit #2 (IHSS 153); and
- 903 Pad (IHSS 112)/Ryan's Pit (IHSS 109).

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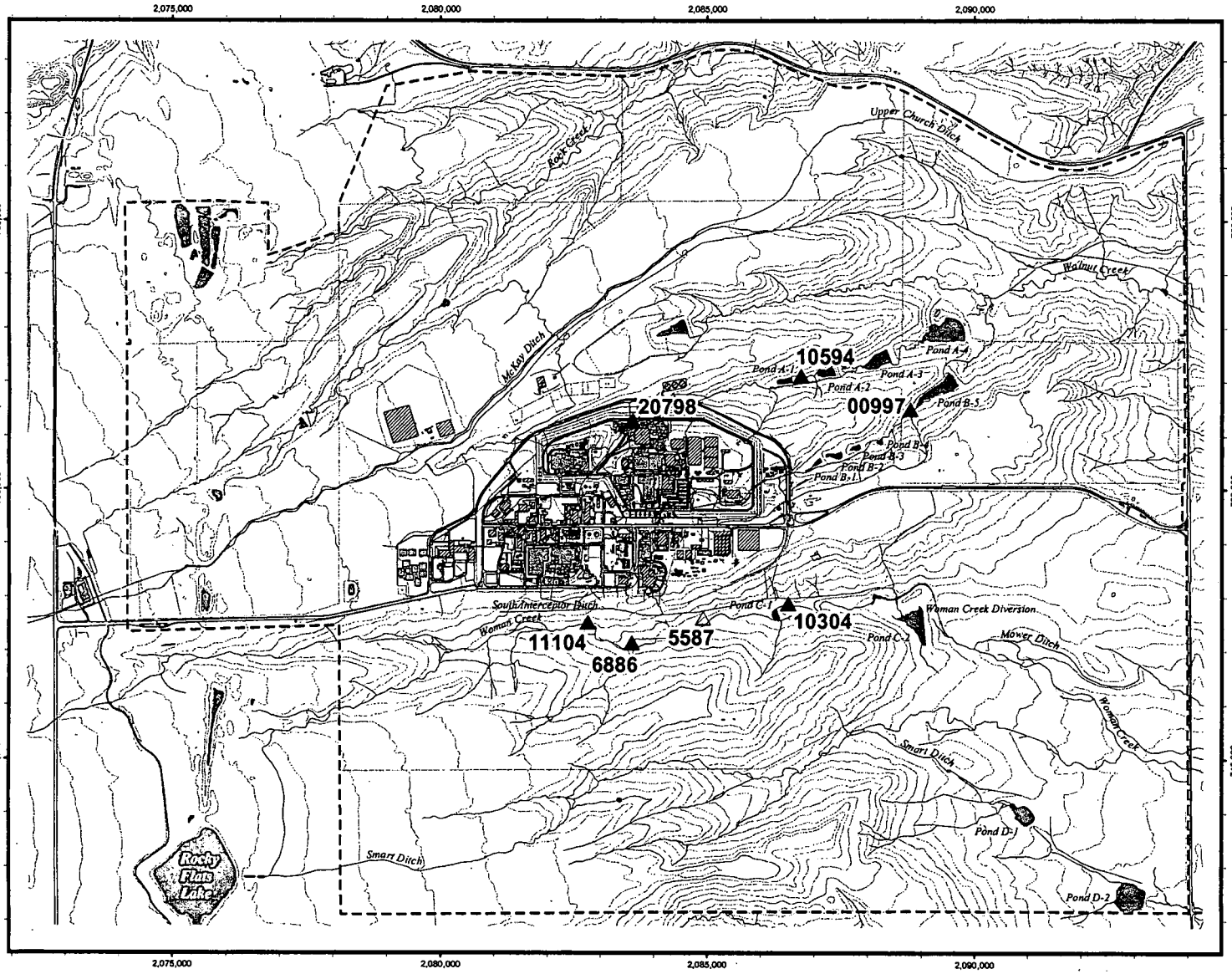

Figure 5-1
Area of Concern Boundary Wells

Legend

- ▲ AOC Boundary Well
- △ Well in Vicinity of New AOC Boundary Well

DRAFT

N
W E
S

Scale = 1 : 36,000
1 inch represents 3,000 feet

1,500 0 1,500 3,000
Scale in Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Date: December 7, 2004

URS

Prepared for:

KAISER•HILL

NT Bvr w:\projects\fy2004\04-0008\AOC Bndry Wells.mxd

6.0 ANALYSIS OF ALTERNATIVES

6.1 Objective

As summarized in Table 5-9, the plumes were divided into:

- Plumes that achieve RAOs. These plumes do not require additional evaluation or accelerated action. Observational monitoring will verify that the RAOs continue to be met (Section 7.7); and
- Plumes that potentially do not achieve RAOs and that require additional evaluation and/or action.

It is not technically practical to completely eliminate groundwater contamination at the Site because of the numerous soil contamination areas that contribute to groundwater contamination, and the diffuse nature of the contaminant plumes. Therefore, alternatives selected will not completely eliminate groundwater contamination but will have relatively long-term, positive impacts to groundwater and surface water quality.

EPA guidance and presumptive remedies focus on groundwater remediation using the following remedies:

- Source removal through excavation or *in-situ* methods;
- Groundwater removal, either by collection trenches or wells, and active treatment; and
- Passive groundwater treatment, either by flow-through barriers, collection trenches and passive treatment, phytoremediation or biodegradation.

Based on Site experience and the previous alternatives analyses evaluations performed for the Mound Site Plume IM/IRA (DOE, 1997a), East Trenches Plume Proposed Action Memorandum (PAM) (DOE, 1999a) and Solar Ponds Plume IM/IRA (DOE, 1999b), alternatives were selected for evaluation that are effective at the Site, provide a long-term, passive solution for groundwater remediation, and minimize water management and treatment costs. These alternatives are:

- Source removal/excavation – Source areas that are well defined and clearly identified as a source of groundwater contamination will be excavated;
- *In-situ* enhanced biodegradation - Additives are used *in-situ* to reduce the contaminant load contributing to groundwater contamination. These additives enhance or improve the naturally occurring bioremediation;
- Phytoremediation – Plants have been proven to be effective in removing contamination in groundwater. Deep-rooted native plants will reduce the contaminant load in groundwater in downgradient areas where the root can intercept contaminated groundwater; and

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- Passive groundwater collection and treatment systems – Groundwater is collected by intercept trenches, then treated in passive treatment cells that contain reactive iron or other treatment media suitable for the groundwater contaminants. These systems are situated at the distal ends of the groundwater plumes, upgradient of where the plumes' discharge to surface water.

Additional alternatives were also previously evaluated but were not considered technically feasible at the Site. These included:

- Source removal/soil vapor extraction – Evaluated previously at the Site (OU 2 Subsurface IM/IRA Site No. 1 Soil Vapor Extraction Pilot Test Report Revision 0 [EG&G, 1994c]). Limited contaminant removal was accomplished, however, the low recovery rates demonstrated that this technology is not practical under Site conditions for remediating contamination contributing to groundwater contamination. Consequently, the soil vapor extraction project was discontinued, and this project site was remediated by excavation (Completion Report for the Source Removal at Trenches T-3 and T-4 (IHSSs 110 and 11.1) RF/ER-96-0051, September [DOE, 1996]). Therefore, this alternative was not selected for further evaluation in this document.

- Groundwater pump and treat – This alternative was evaluated and rejected because of the low groundwater recovery rates from pumping wells as a result of the widespread, low permeability soils on Site. In addition, this is not a passive system, there are relatively high operation and maintenance costs, and this technology is only suitable for the few places on Site where groundwater can be effectively extracted from wells.

- Groundwater collection and non-passive treatment – This alternative was evaluated and rejected because Site groundwater contaminants can be effectively treated in a more cost effective manner in local, passive treatment cells making remote treatment options unfavorable.

Natural attenuation is not a selected remedy for the site. Instead, observational monitoring will be utilized for the remaining plumes to verify that actions will not be required. Observational monitoring will also be utilized to indicate if actions are required if conditions change from the expected.

The selected, reasonable alternatives were evaluated for effectiveness, implementability and relative costs. Relative cost is provided for comparison purposes only and is not based on a site-specific design or cost estimate. It is anticipated that all alternatives selected will have comparable community and stakeholder acceptance because each alternative under evaluation has the potential for accelerating improvement in the protection of surface water quality.

Table 6-1 summarizes the areas with groundwater contamination and the potential actions for each, selected based on the location and contaminants of concern that were selected for further evaluation through the consultative process. The selected preferred alternative for each area may be one or a combination of alternatives.

Table 6-1. Proposed Remedial Action Alternatives by Area Requiring Additional Evaluation

Groundwater Contamination Area Requiring Evaluation	Soil Source Removal/ Excavation	*In-Situ* Enhanced Biodegradation	Phyto-Remediation	Passive Groundwater Collection and Treatment
Carbon Tetrachloride Plume (IHSS 118.1)	Selected for evaluation	Selected for evaluation	Selected for evaluation	Selected for evaluation
Downgradient East Trenches Plume	Source area removal completed	Selected for evaluation	Selected for evaluation	System installed upgradient
Downgradient Solar Ponds Plume	Source area removal completed	Not selected for evaluation	Selected for evaluation	System installed upgradient
Mound/ Oil Burn Pit #2	Completed for Mound Site – Selected for evaluation at the Oil Burn Pit #2	Selected for evaluation	Not selected for evaluation	Evaluate extension of existing Mound Site Plume system
903 Pad/Ryan's Pit	Completed - additional VOC removal selected for evaluation	Selected for evaluation	Not selected for evaluation	Not selected for evaluation

6.2 Carbon Tetrachloride Plume (IHSS 118.1)

The primary contaminant source for groundwater contamination in this area is the IHSS 118.1 Carbon Tetrachloride Spill. The main source area is a small, well-defined area surrounding the subsurface Building 730 process waste tanks. Approximately 5,000 gallons of CT are thought to be present in the subsurface at the structure's base, some as free product. As shown in the nature and extent section of this document, there are high concentrations of CT in a localized area surrounding B730. A more diffuse plume extends to the east and west to a plume area that includes several other VOCs, primarily 1,1-DCE, CF and acetone. Low concentrations of CT have been observed in the footing drains along the western side of Building B771. At this time, the plume does not impact surface water above SWPRGs at the probable discharge location into North Walnut Creek.

Under the ER RSOP, accelerated actions to address the Carbon Tetrachloride Plume were completed in fall 2004. Source removal, *in-situ* biodegradation, phytoremediation and passive collection and treatment were evaluated for this area. Activities planned and completed under the ER RSOP include demolition of the Building 730 structure and removal of the walls and part of the slab, removal of visible liquid CT in the soil surrounding Building 730, removal of contaminated soil and gravel, and application of material to promote *in-situ* biodegradation of residual contamination. In addition, worker safety and working conditions required that groundwater be removed and treated. While not specifically planned under the ER RSOP, this activity also had a positive impact on

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groundwater quality in this area. Source removal and *in-situ* biodegradation will be performed as activities under the ER RSOP, but are evaluated here for completeness.

6.2.1 Source Removal

Source removal is an effective method of reducing contaminant load in the subsurface where the contaminated area can be clearly defined. Excavation was also required for demolition of the Building 730 structure, and access to the contaminated soil and free product CT was obtained at that time.

6.2.1.1 Effectiveness

Excavation is an effective method for reducing contaminant load because this is a well-defined source area. In addition, excavation of the area was required for demolition of the Building 730 structure, and exposed the contaminated soil and groundwater. Although source removal is an effective means for removing the majority of the free product phase source, small amounts of contamination will remain in the environment as a source of groundwater contamination.

Short-term effectiveness - the potential for dust emissions and sediment load to the streams increased during construction but was mitigated through standard construction practices. There was increased potential for release of contaminants to uncontaminated areas during source removal, and an increased risk to the worker from construction accidents and exposure to high concentrations of VOCs. Approximately 250,000 square feet were disturbed to accommodate excavation and staging areas. However, this area is within the IA and is already significantly disturbed. The area requires regrading and vegetation. In addition, disturbing VOC source areas generally results in short-term increased groundwater contamination in the area and downgradient of the excavations.

Long-term effectiveness - there will be a greatly reduced contaminant mass at the source area. Groundwater quality will be slow to improve because of the slow rate of contaminant migration.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) (surface water standards) will continue to be met at the surface water Point of Compliance (POC) for North Walnut Creek, based on the reduced contaminant mass in the source area, distance to surface water, and disruption of the B771 footing drains at closure. The footing drains are the most direct pathways to surface water for this groundwater plume.

6.2.1.2 Implementability

This alternative was readily implemented using standard industry equipment and practices. Available equipment and workers were used for this alternative. RAOs of protecting surface water will be obtained by reducing the contaminant mass present at this location.

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6.2.1.3 Cost

The cost to excavate a contamination source is approximately $300 per cubic yard for the equipment and personnel to excavate contaminated soil and package it into waste containers, and backfill the excavation with clean soil. Waste disposal costs are an additional $700 for each cubic yard of low-level mixed waste. An additional soil treatment cost of $1,000,000 will also be required because the contaminant concentrations exceed Land Disposal Restriction (LDR) levels. Treatment cost is based on historical thermal desorption costs for work previously performed at the Site. For an area of contaminated soil 100 feet by 100 feet by 1 foot thick at a depth of 20 feet, the estimated total cost of this alternative is $1,350,000.

6.2.1.4 Summary

Excavation at the project site was required for Building 730 demolition and resulted in exposure of the contaminated soil. This alternative will be effective in reducing contaminant concentrations in soil at this location.

6.2.2 *In-Situ* Enhanced Biodegradation

Several different types of additives can be used *in-situ* to reduce the contaminant load contributing to groundwater contamination. Two general *in-situ* treatment technologies are considered: *in-situ* enhanced biodegradation and *in-situ* chemical oxidation. The rate of destruction for each varies depending on site-specific conditions and contaminants.

In-situ enhanced biodegradation includes methods that enhance or improve the naturally occurring bioremediation of VOCs through the addition of microorganisms (bioaugmentation) or food substrates, electron acceptors, or other necessary microbial nutrients (biostimulation) into a contaminated media. Amendments must be appropriately matched to the project-specific subsurface conditions and contaminants.

In-situ chemical oxidation involves inserting oxidants and/or other amendments to directly oxidize the contaminants. These methods generally produce relatively non-toxic byproducts such as carbon dioxide, chloride, and water without the production of intermediate toxic daughter products. However, phosgene gas can be produced when oxidizing CT. Because the use of oxidants has a higher worker safety risk than amendments, and oxidants tend to destroy the existing microbial community that may already be degrading the contaminants, *in situ* chemical oxidation was not further evaluated.

Table 6-2 summarizes the common types of *in-situ* enhanced biodegradation amendments that are applicable at this Site. This information was derived in part from an internal report on treatment options.

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Table 6-2. Common Types of Enhanced Biodegradation Amendments

Amendment Type	How It Works	Considered for Further Evaluation?
Microbes	Bioaugmentation - Microbes are added where the native microbes are not effective in removing contamination. Microbes are selected that are known to be successful in remediation of the specific type of contaminant at a given location.	No. Local microbe population is performing some biodegradation.
Reactive iron	Placing zero-valent iron with or without an additional carbon source in the area – this creates a reducing environment and promotes microbial growth which, in turn, enhances biodegradation.	Yes. Selected for evaluation. These types of materials will support the local microbe population and accelerate biodegradation at this site.
Edible oils, sugars, and other organic products	Biostimulation –These products provide nutrients and electron receptors to the existing microbes to enhance biodegradation. Types of products include milk sugar, molasses, fructose, ethanol, semi-solids such as various proprietary slow release compounds and edible oils, and solids such as tree bark and chitin.	Yes. Selected for evaluation. These types of materials will support the local microbe population and accelerate biodegradation at this site.

6.2.2.1 Effectiveness

Short-term effectiveness – Approximately 250,000 square feet of soil were disturbed during Building 730 demolition and source removal. However, the area was already significantly disturbed as part of IA construction and operations. The area requires regrading and vegetation. Dust generation associated with this alternative was minimal.

Workers were exposed to standard construction hazards. The selected amendment is relatively non-toxic, posing low risk to the workers. Implementation will result in release of degradation products to the groundwater system.

Long-term effectiveness – *In-situ* enhanced biodegradation is a viable technology for groundwater remediation at Rocky Flats and has successfully been demonstrated at the PU&D Yard Plume Treatability Study to reduce contaminant load in the soil (K-H 2001b). The amendment used was HRC-X®, which is an extended-life, proprietary, environmentally safe, polylactate ester formulated for slow release of lactic acid upon hydration. It stimulates rapid degradation of chlorinated VOCs found in groundwater and soil by making low concentrations of hydrogen available to the resident microbes to use for dechlorination.

As demonstrated by the PU&D project, HRC® is effective in reducing the contaminant load in soil that contributes to groundwater contamination. It is relatively long acting in this environment and inexpensive. However, there are negative impacts associated with use of amendments. As shown by the treatability study, the reducing amendments have a

surfactant effect and can cause a short-term increase in groundwater contaminant concentrations, and seasonal groundwater contaminant increases, when groundwater rises into contaminants and amendments that are unsaturated in the dry season (K-H, 2001c). The reducing environment produced by the amendments can also cause release of arsenic, and potentially other metals, into the groundwater, although this release appears to be limited in areal extent to less than 10 feet from where the amendments have been introduced.

Regenesis, the maker of HRC®, has stated that degradation of CT will produce MC, which will degrade in oxidizing conditions given sufficient time and distance. However, surface water will not be impacted by use of amendments because of the distance to surface water.

The amendment is not considered as effective in reducing the dissolved-phase contaminants in the plume because of the lower quantities and larger volumes of water, requiring larger populations of bacteria to be present. In addition, amendments were not considered as a sole remedial action, because significant free-phase product was present that was expected to require repeated applications over time to reduce large contaminant masses. At similar locations, the PU&D Yard treatability study recommendation is to couple the use of amendments with other remediation techniques to treat residual contamination.

Compliance with ARARs (surface water standards) – compliance with the standards will continue at the surface water POC location on North Walnut Creek based on the reduced contaminant mass in the source area, the distance to surface water, and disruption of the Building 771 footing drains at closure. The footing drains are the most direct pathways to surface water for this groundwater plume. Additional compliance criteria are discussed in Section 9.0.

6.2.2.2 Implementability

A variety of products are commercially available (see Table 6-2) and proven installation methods have been identified. HRC-X® was selected for implementation at this project site during the project planning phase of the work because of its persistence and effectiveness for several years, and its ability to stimulate biodegradation of CT. In addition, this product was previously proven effective at RFETS during the PU&D Yard treatability study. Application will take place one time only to support the RAO of reducing the contaminant mass that might impact surface water.

6.2.2.3 Cost

The cost for the PU&D Yard project was approximately $100,000, including installation of two monitoring wells and monitoring for one year. Because removal of liquid CT and contaminated soil has occurred and because the extended-life HRC-X® was used, repeat applications of amendments are not expected. If the contaminated source material was still present at this location and this was to be the primary alternative, the cost is estimated at approximately $200,000. The cost for application in conjunction with other

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remedial activities is anticipated to be the same as for the PU&D Yard, approximately $100,000.

6.2.2.4 Summary

In-situ biodegradation is not viable as the primary remedial action for IHSS 118.1 because of the high contaminant concentrations present. However, there is benefit to using this method in conjunction with source removal to further reduce residual contamination at this site and reduce the impact of a removal action on groundwater quality.

6.2.3 Phytoremediation

Passive phytoremediation is an effective method for reducing the contaminant load in groundwater and is best suited to downgradient areas where deep-rooted native plant species can intercept shallow groundwater.

The IHSS 118.1 area is not appropriate for phytoremediation because of the distance to surface water and the low groundwater flows in the area. Therefore, this alternative is not selected as a primary alternative. However, modeling results indicate that a downgradient area in the drainage between Buildings 371 and 771 should continue to contain at least some groundwater after Site closure. This could at least partly sustain the already established vegetation near the creek. However, no attempts would be made to replace dead or dying vegetation as these areas would not be suitable for continued, effective phytoremediation.

6.2.3.1 Effectiveness

Short-term effectiveness – No additional areas will be disturbed because the vegetation is already in-place.

Long-term effectiveness – Phytoremediation is a seasonal process that will address approximately 10 to 15 percent of the ambient concentrations for TCE. Uptake rates for other organic compounds are higher. Effectiveness depends on the season, contaminant, hydrogeologic conditions, and other factors. Phytoremediation both removes the contaminants from groundwater and reduces the volume of groundwater flowing through the area via ET. Modeling results show that relatively low concentrations of CT, slightly above the SWPRG, may be present in this drainage. The existing plants will reduce these projected very low concentrations during the active growing season.

Compliance with ARARs – No change in the compliance with ARARs is anticipated as a result of phytoremediation. However, reduction of contamination load and a decrease in water would occur during the growing season. No reduction is anticipated during the winter. ARARs (surface water standards) are anticipated to be achieved at the North Walnut Creek surface water POC because of the source removal and amendment placement.

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6.2.3.2 Implementability

An established plant population is already present at this location. No further implementation is required.

6.2.3.3 Cost

An established plant population is already present at this location. No further costs to establish or maintain this population is required.

6.2.3.4 Summary

Phytoremediation is not technically feasible for this area as a primary alternative. However, within the drainage between Buildings 371 and 771, the existing, established plant population will provide some limited additional remediation.

6.2.4 Passive Collection and Treatment

This system passively collects groundwater in trenches, then treats the captured groundwater in passive treatment cells that contain reactive iron. These systems are situated at the distal ends of the groundwater plumes, upgradient of where the plumes discharge to surface water.

6.2.4.1 Effectiveness

Short-term effectiveness – Dust emissions and sediment load to the streams would increase during construction of the collection trench and treatment cells and would be mitigated through standard construction practices. A relatively large area would be disturbed. Therefore, this alternative would be considered only in areas that are not located in sensitive environments such as wetlands or Preble's Meadow Jumping Mouse (PMJM) habitat. Risk is increased to the worker from construction accidents.

Long-term effectiveness – This alternative is effective in cases where the groundwater plume is predicted to reach or has already reached surface water. The downgradient part of the contaminant plume is intersected and treated to reduce the contaminant load to surface water. However, the groundwater modeling indicates the Carbon Tetrachloride Plume is not a threat to surface water above SWPRGs unless groundwater flow is captured and funneled to surface water. Based on these groundwater model results (see Appendix D), no impact to surface water is anticipated from this plume at the POCs.

Compliance with ARARs – Water discharged from the treatment cells would meet ARARs (surface water standards). Surface water standards would be met at the surface water POC on North Walnut Creek.

6.2.4.2 Implementability

While this alternative is readily implemented using standard industry equipment and practices, for this location, contaminated groundwater cannot be readily intercepted in quantities that justify treatment. Installation of previous systems at the Site have encountered slope stability problems during construction. Currently available equipment

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and workers would be used. Bench-scale tests are required to determine the appropriate treatment media and will take approximately 3 months.

6.2.4.3 Cost

The cost is approximately $1,500,000 for installation of a groundwater collection and treatment system, including monitoring for one additional year. Annual maintenance costs are generally $20,000 to $40,000 per year. Media replacement due to plugging or exhaustion of iron media is anticipated to cost approximately $100,000 and is expected to be required every five years for a system this size.

6.2.4.4 Summary

For the Carbon Tetrachloride Plume, this alternative has the highest implementation cost, can have high maintenance costs, and is technically feasible, but is less readily implementable than other alternatives because contaminated groundwater cannot be readily intercepted in quantities that justify treatment. Therefore, there would be little positive impact to surface water quality, change in mass loading to the stream, or change in plume extent as a result of implementing this alternative. No reduction in the contaminant source area mass would result at this well-defined source area.

6.2.5 Preferred Alternative

Comparison of the evaluated alternatives is shown in Table 6-3. Source removal was the preferred alternative because the contamination is well defined, contained within a small area surrounding Building 730, and exposed during demolition of the structure. This alternative is the most effective in reducing the volume of contamination present. Because complete source removal is not possible, *in-situ* enhanced biodegradation was used in conjunction with source removal to further reduce contaminant concentrations and impacts to groundwater.

Modeling results show that low levels of contamination in groundwater may reach the drainage between the Building 371 and 771 areas. Phytoremediation associated with the existing vegetation in this area will also reduce these contaminants in this area. Passive groundwater collection and treatment as a sole remedy is less effective than source removal in combination with *in-situ* enhanced biodegradation and limited phytoremediation. Passive groundwater collection and treatment coupled with source removal is no more effective than the preferred alternative, yet the cost is significantly more.

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Table 6-3. Comparison of Groundwater Remediation Alternatives for the Carbon Tetrachloride Plume (IHSS 118.1)

Alternative	Description	Effectiveness	Implement-ability	Comparative Cost
Source Removal	Excavation and disposal of well-defined VOC contaminated soil and associated free-phase CT.	Effective in reducing high volumes of contaminated soil present at source areas. Complete source removal is not possible. Increased short-term groundwater contamination often seen following actions.	High – readily implemented	Moderate to High - $350,000 to $1,500,000 (depending on soil treatment cost)
In-situ Enhanced Biodegradation	Using *in-situ* additives to reduce contaminant mass	Effective in reducing residual contaminant load. Would not effectively eliminate existing contaminant levels in source area.	High – readily implemented	Low to Moderate- $200,000
Phyto-remediation	Utilizing existing vegetation to reduce contaminant and water load to surface water	No reduction in the winter.	High – already implemented	No additional costs
Passive collection and treatment	Installation of a passive collection trench and treatment cells to capture and treat contaminated groundwater	Groundwater plume is neither currently impacting nor predicted to impact surface water above SWPRGs at Walnut Creek POC. Significant volume of contaminated groundwater would not be captured. Does little to reduce mass loading to surface water.	Moderate – readily implemented, slope stability problems anticipated during construction and potentially wetland and PMJM issues	High - $1,500,000

6.3 Downgradient Portion of the East Trenches Plume

A source removal was completed at the East Trenches area in 1996 and a 1,200-foot-long passive groundwater collection and treatment system was installed in 1999. However, a portion of the plume is located north of the collection system and is not being collected. This portion of the plume impacts surface water above SWPRGs. This area is immediately adjacent to South Walnut Creek and is approximately 750 feet long and up to 100 feet wide. In 2003, the maximum VOC concentrations observed at this portion of the plume were seen at well 23296. Concentrations were 408 µg/L TCE and 20 µg/L PCE, well above the RFCA groundwater ALs of 5 µg/L for each. These concentrations have not significantly declined since installation of the East Trenches Collection System.

In addition, VOC concentrations in the B-Series ponds have been noted, particularly during winter when the ponds freeze over. In February 1997, TCE in the B-2 Pond was observed at concentrations approximating 400 µg/L. TCE concentrations at seeps at the

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edge of the B-2 Pond were up to 970 µg/L. PCE and cis-1,2-DCE were also observed, but at lower concentrations (DOE 1999a). These data are corroborated by recent CDPHE samples at the B-2 Pond.

The alternatives evaluated for this part of the plume are *in-situ* enhanced biodegradation and phytoremediation. Extending the existing groundwater collection system closer to South Walnut Creek was not considered because of the problems in construction on the steep hillside in wetlands areas, and the likelihood that water from the stream and ponds would also be captured, increasing and diluting the volume of water captured.

6.3.1 *In-Situ* Enhanced Biodegradation

In-situ enhanced biodegradation includes methods that enhance or improve the naturally occurring bioremediation of VOCs through the addition of microorganisms (bioaugmentation) or food substrates, electron acceptors, or other necessary microbial nutrients (biostimulation) into a contaminated media. Amendments must be appropriately matched to the project-specific subsurface conditions and contaminants and are added directly into the subsurface. For this evaluation, a slow release nutrient was considered as being the most appropriate based on previous experience at the Site, ease of implementation, and effectiveness. The method for applying the amendments used at the Site is to place the material in Geoprobe boreholes drilled within the highest concentration area of the plume. The Geoprobe holes are placed at an appropriate grid spacing to cover the area, and generally extend slightly into the weathered bedrock. For evaluation purposes, the application area is anticipated to be approximately the length of the collection system from the trench downgradient to South Walnut Creek. However, this length would be evaluated during the project planning phase and may be limited to the immediate area where there are elevated values present in the groundwater.

6.3.1.1 Effectiveness

Short-term effectiveness – This alternative would result in disturbance to natural conditions, including PMJM habitat and wetlands. An area approximately 1,200 feet long by 200 feet wide would be disturbed. Workers would be exposed to standard construction hazards. However, most amendments are relatively non-toxic and are often of food-grade quality, posing low risk to the workers. Implementation would result in release of degradation products to the groundwater system.

Long-term effectiveness – *In-situ* enhanced biodegradation is a viable technology for groundwater remediation at Rocky Flats and has successfully been demonstrated at the PU&D Yard Plume Project using HRC® to reduce contaminant load. HRC® is effective in reducing the contaminant load in soil that contributes to groundwater contamination. HRC® is relatively long acting in this environment, inexpensive, and effective. Other types of amendments are anticipated to be equally effective.

As described in Section 6.2.1.1, use of amendments is anticipated to cause a three to four month increase in groundwater contaminant concentrations because of the surfactant effect when the amendments are added, and may cause sporadic increases later if water

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levels drastically rise and fall. Degradation of the contaminants forms VC, which is more toxic than the initial contaminants. VC and other byproducts would further degrade if there is sufficient time and/or distance to surface water. In addition, as discussed in Section 6.2.1.1, arsenic may be locally released into groundwater as a result of insertion of amendments. The extent of the dissolved-phase arsenic is very limited, but may potentially impact surface water.

Because of the proximity to surface water, impacts to surface water would initially be expected that are greater than the current conditions.

Compliance with ARARs – Compliance with ARARs (surface water standards) for the original contaminants would be expected within five years.

6.3.1.2 Implementability

A variety of products are commercially available and proven installation methods have been identified. Sufficient data are available to determine the appropriate product or range of products for any given site. Identification of the appropriate product would take place during the implementation phase of the Groundwater IM/IRA.

The downgradient plume area is steeply sloping and within wetlands and PMJM habitat. Problems are expected implementing this remedy using existing commercially available equipment and techniques because of the slopes, amount of vegetation, and some unstable ground. There would be areas where insertion of material is not possible, or would be limited by local conditions. Insertion would be a one-time application and would not be intended to fully remediate the groundwater plume.

6.3.1.3 Cost

The cost of this remedy is anticipated to be approximately $300,000 regardless of the media used based on the PU&D Yard project costs.

6.3.1.4 Summary

Impacts to surface water from the adjacent groundwater would initially increase because of the plume area's proximity to South Walnut Creek. Surface water impacts could result from the surfactant-induced increase in VOC groundwater contaminants including releasing degradation byproducts such as VC to surface water that are more toxic than the original contaminants. Localized surface water impact from increased metals contaminants in groundwater may also occur after amendments are added.

6.3.2 Phytoremediation

Passive phytoremediation is an effective method for reducing the contaminant load in groundwater and is best suited to downgradient areas where deep-rooted native plant species can intercept shallow groundwater. The genus *Populus* and, to a lesser extent, other members of the willow family (*Salicaceae*) have been shown to be effective in phytoremediation applications (Licht and Schnoor, 1993; Newman et al., 1997). At least six species of poplars, cottonwoods and willows are found at RFETS, most of which

would be suitable for phytoremediation (DOE, 1994b). The number of trees required for phytoremediation at the SPP Project will be determined based on the specific characteristics of the project site.

While much of the area suitable for the phytoremediation enhancement can sustain young plants, some areas are drier and may require supplemental irrigation for the first year. No irrigation is planned after the first year because plants that cannot be established in this time frame will not effectively remove contaminants and will be allowed to die. No attempts will be made to replace dead or dying vegetation as these locations would not be suitable for continuing phytoremediation. Modeling results indicate that there will be continued groundwater in this immediate area after Site closure that could sustain vegetation near the creek, once it is established.

6.3.2.1 Effectiveness

Short-term effectiveness –This alternative would result in disturbance to natural conditions, including plume areas within PMJM habitat or wetlands. The areas would be disturbed during deep tree planting, by temporary roadways to the planting areas and temporary irrigation systems for the first year, if required. Workers would be exposed to standard construction hazards. Dust emissions and sediment load to the streams would increase during construction and would be mitigated through standard construction practices.

Long-term effectiveness – Phytoremediation is a seasonal process that would address approximately 10 to 15 percent of the ambient concentrations for TCE with higher uptake rates for other organic compounds (Newman et al., 1997). Effectiveness depends on the season, contaminant, hydrogeologic conditions, and other factors. Phytoremediation both removes the contaminants from groundwater and reduces the volume of groundwater flowing through the area via active uptake during the growing season. Reduction in the contaminants during this time would have a positive impact on the groundwater quality. Approximately 4 years are required to achieve this peak removal rate; however, limited remediation would take place earlier.

Compliance with ARARs – Reduction of contamination load and a decrease in water would occur during the growing season. No remediation is anticipated during the winter. However, it is anticipated that ARARs (surface water standards) would be met at the South Walnut Creek surface water POC because of the reduction in groundwater contaminants during the growing season.

6.3.2.2 Implementability

This alternative is technically feasible with native plant species, as well as standard industry equipment and planting practices. Because of the proximity to South Walnut Creek with a relatively constant water supply, this system is anticipated to be sustainable in areas nearest the creek, even in drought years. Groundwater modeling corroborates this, where even with the reduced stream volume, underflow is predicted to occur in the stream alluvium (Appendix D).

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The downgradient plume area is steeply sloping and within wetlands and PMJM habitat. There would be problems with implementing this remedy using existing commercially available equipment and techniques because of the slopes, amount of vegetation, and unstable ground. Areas exist where additional vegetation could not be planted because of existing vegetation, including wetland vegetation, very steep slopes, or limited by other local conditions.

6.3.2.3 Cost

The cost is approximately $75,000 for establishing and maintaining a 1- to 2-acre phytoremediation system for one year.

6.3.3 Preferred Alternative

Comparison of the evaluated alternatives is shown in Table 6-4. Phytoremediation is technically feasible and would reduce contaminant loads and water supply in the growing season. No remediation is anticipated during the winter. This alternative is best suited for areas near the streams with a continual source of contaminated water where additional reduction in contaminant load to the streams is required. For these reasons, phytoremediation is the preferred remedy for the downgradient portion of the East Trenches Plume.

Table 6-4. Comparison of Groundwater Remediation Alternatives for the Downgradient Portion of the East Trenches Plume

Alternative	Description	Effectiveness	Implement-ability	Comparative Cost
In-situ Enhanced Biodegradation	Using *in-situ* additives to reduce contaminant mass	Effective in reducing residual contaminant load. Would not effectively eliminate existing contaminant levels. Potential to release more toxic degradation products to surface water due to proximity to surface water.	High – readily implemented	Moderate - $300,000
Phyto-remediation	Planting native species with high water consumption to reduce contaminant and water load to surface water	Effective in reducing contaminant loads during the active growing season. No remediation in the winter. Limited to areas with constant water supply such as near streams. Requires disruption of sensitive habitats.	High – readily implemented	Low - $75,000

6.4 Downgradient Portion of the Solar Ponds Plume

The SEPs were closed in 2002. In 1999, a 1,100-foot-long passive groundwater collection and treatment system was installed to collect and treat the contaminated

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groundwater plume. However, a portion of the plume is located downgradient of the collection system that continues to persist. Based on the available well data, the area of highest groundwater contamination within the downgradient residual plume appears to be immediately adjacent and downgradient of the previous pump house and sump for the Interceptor Trench System (ITS). The ITS drained the hillside prior to installation of the SPP Collection System. The area with the highest nitrate groundwater contamination is roughly estimated at approximately 200 square feet and is immediately adjacent to North Walnut Creek. This portion of the plume contributes to the higher concentrations seen at the discharge gallery for the SPP System (located in this area) than observed in the treatment system effluent.

Of the proposed alternatives, a source removal was previously completed as part of the SPP closure, and a collection and treatment system is already installed upgradient of this part of the plume. Installation of a collection system in this location would result in the capture of water from Woman Creek if the system was installed at a depth below the water level in the Creek. An additional groundwater treatment cell would need to be installed, and located a relatively long distance downstream to obtain the hydraulic head required to operate a passive, flow-through system.

While both *in-situ* biodegradation and phytoremediation were initially considered for this part of the plume, the *in-situ* biodegradation alternative was eliminated because of technical impracticability. As described in the SPP Decision Document (DOE, 1999b), use of organic liquids, such as molasses, that result in nitrate degradation in close proximity to the stream are expected to increase the biological oxygen demand in the stream and have negative impacts on the existing biota. Injection of a zero-valent iron curtain is an effective way to remove uranium from groundwater. However, without a carbon source and appropriate residence time, nitrates are reduced to ammonia, potentially causing release of ammonia into the adjacent stream. Phytoremediation was then selected for further evaluation.

6.4.1 Phytoremediation

Passive phytoremediation is an effective method for reducing the nitrate contaminant load in groundwater and is best suited to downgradient areas where deep-rooted native plant species can intercept shallow groundwater. As discussed in the SPP Decision Document (DOE, 1999b), phytoremediation is also effective in reducing uranium concentrations in groundwater. In the long-term, there is a possibility that removed plant material may need to be dispositioned as low-level waste if uranium concentrations are sufficiently high. The genus *Populus* and, to a lesser extent, other members of the willow family have been shown to be effective in phytoremediation applications. At least six species of poplars, cottonwoods, and willows are found at Rocky Flats, most of which would be suitable for phytoremediation. The number of trees required for phytoremediation at the SPP Project will be determined based on the specific characteristics of the project site.

While much of the area suitable for phytoremediation can sustain young plants, some areas are drier and may require supplemental irrigation for the first year. No irrigation is

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planned after the first year because plants that cannot be established in this time frame will not effectively remove contaminants and will be allowed to die. No attempts will be made to replace dead or dying vegetation, as these locations would not be suitable for continuing phytoremediation. Modeling results indicate that there would be continued groundwater in this immediate area after Site closure that could be sufficient to sustain established vegetation near the creek.

6.4.1.1 Effectiveness

Short-term effectiveness – This alternative would result in disturbance to natural conditions, including plume areas within PMJM habitat or wetlands. The areas would be disturbed during deep tree planting and by temporary roadways to the planting areas and temporary irrigation systems if required. Workers would be exposed to standard construction hazards. Dust emissions and sediment load to the streams would increase during construction and would be mitigated through standard construction practices.

Long-term effectiveness – Because nitrate is a major component of fertilizers, phytoremediation is effective in reducing this contaminant. Phytoremediation is a seasonal process that is expected to reduce approximately one-third of the contaminant loading for nitrates. Approximately four years are required to achieve the peak nitrate removal rate (Licht and Schnoor, 1993). Based on previous work for the SPP Project, uptake of the groundwater by plants tends to reduce and trap uranium, reducing the uranium contamination in groundwater (DOE, 1999b). Phytoremediation is only effective during the active growing season, and does not occur during the winter. Phytoremediation both removes the contaminants from groundwater and reduces the volume of groundwater flowing through the area via active uptake.

The discharge gallery is currently situated at the lowest possible location. Passively diverting water from the current collection system for irrigation is not feasible because of the low gradient from the ITS intersection to the discharge gallery. However, the area around the discharge gallery can be heavily planted. Because the flow in this area persists to some extent even under drought conditions, this area is expected to be able to sustain established plants even under severe drought conditions.

Compliance with ARARs – Reduction of contamination load and a decrease in water would occur during the growing season. No remediation is anticipated during the winter. However, it is anticipated that ARARs (surface water standards) would be met at the North Walnut Creek surface water POC because of the reduction in groundwater contaminants during the growing season.

6.4.1.2 Implementability

This alternative is technically feasible with native plant species, standard industry equipment and standard planting practices.

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6.4.1.3 Cost

The estimated size of the phytoremediation system at the downgradient SPP is approximately one to two acres. The estimated cost is $75,000 for establishing a phytoremediation system of this size and maintaining it for one year.

6.4.2 Preferred Alternative

The selected alternative of phytoremediation is summarized in Table 6-5. Phytoremediation is technically feasible, has low cost, and would reduce contaminant loads and water supply in the growing season although no remediation is anticipated during the winter. This alternative is best suited for areas near the streams with a continual source of contaminated water where additional reduction in contaminant load to the streams is required. For these reasons, phytoremediation is the preferred remedy for this plume.

Table 6-5. Phytoremediation Evaluation for the Downgradient Portion of the SPP

Alternative	Description	Effectiveness	Implement-ability	Comparative Cost
Phyto-remediation	Planting native species with high water consumption to reduce contaminant and water load to surface water	Effective in reducing contaminant loads during the active growing season. No remediation in the winter. Limited to areas with constant water supply. Disruption of sensitive habitats.	High – readily implemented	Low - $75,000

6.5 Mound Site/Oil Burn Pit #2 Plume

The Mound Site/Oil Burn Pit #2 Plume is located north of Central Avenue, and east of the former PA fence. Two source areas contribute to this groundwater plume: the Mound Site (IHSS 113) and (2) the Oil Burn Pit #2 (IHSS 153). A source removal for the Mound Site was completed in 1998. The Oil Burn Pit #2 is located immediately west of the Mound Site. This was recently characterized and found to be a localized but diffuse source of VOCs and PCBs. An accelerated action for soil source removal will be performed under the ER RSOP to remediate the PCB contamination at this project site.

This removal action will also reduce the amount of colocated VOC contamination in the soil at this location. A source removal for the VOCs was not considered because the contamination is relatively diffuse and would not be as effectively remediated by removal. In addition, results of the Subsurface Soil Risk Screen determined that no action was required for VOC contamination.

The plume of VOC-contaminated groundwater that results from the Mound Site and the Oil Burn Pit #2 source areas extends northward toward South Walnut Creek. Near South Walnut Creek, the plume is captured and treated by the Mound Site Plume groundwater collection and treatment system that was installed in 1998 (DOE, 1997a). Because of the

recently discovered additional source for this plume, the portion of the plume associated with the recently characterized Oil Burn Pit #2 is included in this evaluation. The alternatives evaluated are extension of the existing Mound Site Plume collection system, and *in-situ* enhanced biodegradation at the Oil Burn Pit #2 location.

Phytoremediation was initially considered for a small, wet area along the former PA fence. However, phytoremediation was not further evaluated because the area is very limited in extent and upgradient of the groundwater collection system. There is no net benefit from treating this groundwater. It is doubtful that sufficient water supply will be present after closure to sustain plants not immediately adjacent to South Walnut Creek.

6.5.1 Source Removal

Excavation is required to remediate the PCB-contaminated soils above action levels and will be performed under the ER RSOP. Because the PCB contamination is located in an area of diffuse VOC contamination, this source removal will also reduce the volume of VOC contamination in the subsurface. However, this action is not intended to be a remedial action for the VOC contamination at this project site.

6.5.1.1 Effectiveness

Excavation is an effective method for reducing contaminant load. However, contamination will remain in the environment as a source of groundwater contamination.

For the short term, dust emissions and sediment load to the streams would be increased during construction but would be mitigated through standard construction practices. There would be increased potential for release of contaminants to uncontaminated areas during source removal, and an increased risk to the worker from construction accidents and exposure to PCBs and VOCs. Approximately 10,000 square feet will be disturbed to accommodate excavation and staging areas. However, this area is within the IA and is already significantly disturbed. The area requires regrading and vegetation. In addition, disturbing VOC source areas generally results in a short-term increase in groundwater contamination in and downgradient of the area.

For the long-term effectiveness, there will be reduced contaminant mass at the source area. Groundwater quality would be slow to improve because of the slow rate of contaminant migration.

Compliance with ARARs (surface water standards) would continue to be met at the surface water POC based on the existing groundwater collection and treatment system.

6.5.1.2 Implementability

This alternative would be readily implemented using standard industry equipment and practices. Available equipment and workers would be used for this alternative. Remedial action objectives of protecting surface water would be supported by reducing contaminant mass present at this location.

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6.5.1.3 Cost

Cost to excavate a contamination source is around $300 per cubic yard for the equipment and personnel to excavate contaminated soil and package it into waste containers, and to backfill the excavation with clean soil. Waste disposal costs are an additional $700 for each cubic yard of low-level mixed waste. For an area of contaminated soil 10-feet by 10-feet by 10-feet thick, the estimated total cost of this alternative is $50,000.

6.5.1.4 Summary

Excavation at the project site is required for remediation of PCBs at this project site and would be effective in reducing contaminant concentrations in soil at this location.

6.5.2 *In-Situ* Enhanced Biodegradation

As described in Table 6-2, several different types of additives can be used *in-situ* to reduce the contaminant load contributing to groundwater contamination. Amendments must be appropriately matched to the project-specific subsurface conditions and contaminants. For this area, a slow-release nutrient source was considered as the most likely amendment based on previous success at the Site.

6.5.2.1 Effectiveness

Short-term effectiveness – Approximately 2,500 square feet would be disturbed in the area of the highest soil contamination. However, the Oil Burn Pit #2 area requires regrading and vegetation as part of Site closure, resulting in a much larger disturbed area. Dust generation would be minimal. Workers would be exposed to standard construction hazards. Most amendments are relatively non-toxic and are often of food-grade quality, posing low risk to the workers. Implementation would result in release of degradation products to the groundwater system.

Long-term effectiveness – *In-situ* enhanced biodegradation is a viable technology for groundwater remediation at Rocky Flats and has successfully been demonstrated at the PU&D Yard Plume Project to reduce contaminant load. HRC® is effective in reducing the contaminant load in soil that contributes to groundwater contamination. It is relatively long acting in this environment, inexpensive, and effective. Other similar types of amendments are also anticipated to be equally effective.

Compliance with ARARs (surface water standards) – Compliance with the standards would be met at the surface water POC location for South Walnut Creek based on the reduced contaminant mass, distance to surface water, and presence of the Mound Site Plume Collection and Treatment system downgradient of the source area.

6.5.2.2 Implementability

A variety of products are commercially available and proven installation methods have been identified. Identification of the appropriate product would take place during the implementation phase of the Groundwater IM/IRA.

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6.5.2.3 Cost

The cost for the Oil Burn Pit #2 area is anticipated to be approximately $100,000, including installation of two monitoring wells and monitoring these for one year, regardless of the amendment selected. The cost is based on the PU&D Yard Project.

6.5.2.4 Summary

In-situ biodegradation would not reduce the volume of contaminated groundwater reaching surface water because of the existing collection and treatment system. There is some benefit to using this alternative to reduce the residual contamination at the Oil Burn Pit #2. The distance to surface water and presence of the existing groundwater collection system will minimize impacts on surface water from the degradation products.

6.5.3 Extension of the Existing Mound Site Plume Collection and Treatment System

The Mound Site Plume passive groundwater collection and treatment system was installed in 1998 and continues to be operational. This system consists of a 220-foot-long collection trench with two passive treatment cells containing reactive iron. This system was installed prior to verification that the Oil Burn Pit #2 also contributed to the groundwater contamination for this plume. The system was evaluated to determine whether the existing system sufficiently captures the portion of the groundwater plume that results from the Oil Burn Pit #2, or whether an extension of the collection system is required.

6.5.3.1 Current System Extent Evaluation

The Mound Site Plume groundwater collection system does not extend across the former area of the PA fence south of the Oil Burn Pit #2 area. To cover this area, the existing collection system would need to be extended another 250 feet. As was done for the original collection system, extending the collection system would require that a trench be excavated to bedrock west of and along the alignment of the original collection system. An impermeable barrier would be installed on the downgradient side of the trench, and the bottom of the trench would be filled with bentonite. Sand and a perforated pipe would be installed upgradient of the barrier over the bentonite layer to collect the groundwater. The extension would be tied in to the original collection trench so that all collected groundwater would be directed to the treatment cells.

Evaluation of existing data indicates that this extension is not required as much of this portion of the plume is already captured. As described in detail in Appendix G, prior to system installation, the Mound Site Plume discharged at less than two gallons per minute as seeps and subsurface flow into the South Walnut Creek drainage, primarily at seep SW059. During installation of the Mound Site Plume collection system, the excavation intersected a french drain approximately 18 inches in diameter and consisting of cobble-sized river rock wrapped in geotextile. Utility drawings show that this french drain is approximately 235 feet long, running roughly southwest-northeast across the PA fence area. The french drain was possibly installed to drain the swampy ground east of

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Building 991. The french drain was found at or near the claystone bedrock surface and below the fill material placed during construction of the PA fence.

Very little water was present during construction of the collection system until encountering the french drain. At that time, the amount of water collected by the french drain affected the stability of the excavation walls, causing local collapse (Figure 6-1).

Figure 6-1. Mound Site Plume Collection System Where French Drain Was Intersected

The alignment of the french drain observed in the field intersects the SW059 location and was the most likely cause of this seep. Slightly different contaminants have been observed at SW059 with respect to the rest of the Mound Site Plume which reflects two contaminant sources: the Mound Site (containing mostly PCE and TCE) and the Oil Burn Pit #2 (with various VOC contaminants including PCE, TCE, 1,1-trichloroethane [TCA] and CT).

While the original purpose and extent of the french drain is not known, it intersects groundwater flow in the previous area of the PA fence, including from the Oil Burn Pit #2, and potentially from within the PA. Based on the flow rate observed at SW059 (primarily from the french drain), and the amount of water discharged from the french drain during construction activities for the Mound Site Plume, most of the water in the Oil Burn Pit #2 portion of the plume is captured by the existing french drain. Water from the french drain flows into the Mound Site Plume collection and treatment system.

6.5.3.2 Effectiveness

The combined Mound Site/Oil Burn Pit #2 Plume is already captured and treated. The effectiveness of the existing system is discussed in more detail in Appendix G. The effectiveness of extending the existing collection system is evaluated below.

Short-term effectiveness - For the short term, dust emissions and sediment load to the streams would increase during excavation for the collection trench and treatment cells

that would be mitigated through standard construction practices. A relatively large area would be disturbed. Therefore, this alternative would be considered only in areas that are not located in sensitive environments such as wetlands or PMJM habitat. There is an increased risk to the worker from construction accidents.

Long-term effectiveness – The plume is already being captured by the existing Mound Site Plume collection system in conjunction with the french drain. An extension of the collection system would not capture significantly more groundwater than is currently collected.

Compliance with ARARs – Water discharged from the treatment cells would meet ARARs (surface water standards). Standards would be met at the applicable surface water POCs in South Walnut Creek.

6.5.3.3 Implementability

The plume is already captured. If an extension of the collection system was required, it would be readily implemented using standard industry equipment and practices. Currently available equipment and workers would be used.

6.5.3.4 Cost

The cost is approximately $750,000 for installation of an extension to the existing groundwater collection system.

6.5.3.5 Summary

This alternative has the highest implementation cost and is technically feasible. However, little incremental benefit to surface water quality or reduction in contaminant mass or migration would result from implementing this alternative.

6.5.4 Preferred Alternative

Comparison of the evaluated alternatives is summarized in Table 6-6. The existing collection system is sufficiently capturing the Mound Site/Oil Burn Pit #2 Plume and no extension is required based on the evaluation presented in Appendix G. Use of *in-situ* enhanced biodegradation would reduce the residual contamination at the Oil Burn Pit #2 and the amount of time required for plume degradation to be completed. The distance to surface water and the presence of the existing groundwater collection system will minimize impacts on surface water from the degradation products. Therefore, *in-situ* enhanced biodegradation in conjunction with the planned excavation for the PCB contaminated soils is the preferred alternative. The amendment is anticipated to consist of a one-time application of a slow-release nutrient source; however, this will be additionally evaluated during project planning.

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Table 6-6. Comparison of Groundwater Remediation Alternatives for the Mound /Oil Burn Pit #2 Plume

Alternative	Description	Effectiveness	Implement-ability	Comparative Cost
Source Removal	Excavation and disposal of VOC contaminated soil associated with the PCB contamination requiring remediation.	Effective in reducing the amount of VOC contaminated soil present. Complete source removal is not possible. Increased short-term groundwater contamination often seen following actions.	High – readily implemented	Moderate - $50,000
In-situ Enhanced Biodegradation	Using *in-situ* additives to reduce contaminant mass	Effective in reducing residual contaminant load. Would not have an impact on surface water quality.	High – readily implemented	Low - $100,000
Passive Collection and Treatment	Extension of the existing passive collection trench to capture potentially contaminated groundwater	Groundwater plume is not currently impacting surface water. No additional contaminated groundwater would be intercepted at this time.	High – readily implemented	High - $750,000

6.6 903 Pad/ Ryan's Pit Plume

The 903 Pad/Ryan's Pit Plume originated from releases that occurred at the 903 Storage Area (IHSS 112) and Ryan's Pit (IHSS 109). The primary contaminants in the 903 Pad/Ryan's Pit Plume are CT, TCE, and PCE. Groundwater flow is complex and primarily controlled by bedrock surface features, interactions between geologic units, and variations in saturated thickness. Groundwater flow paths in alluvial materials in the 903 Pad and Ryan's Pit area are relatively well defined by contact seeps with the underlying bedrock materials and by numerous wells. Areas of unsaturated colluvium are common and prediction of local flow paths is difficult. Depending on the season, there are many unsaturated areas within the plume.

Source removals were completed for Ryan's Pit and the 903 Pad areas in 1996 and 2003, respectively. However, residual contamination remains in the Ryan's Pit area, and the nature of the remaining VOC source area at the 903 Pad has not yet been determined. Based on information obtained during the 903 Pad remedial action, one or more localized VOC sources may be present that may potentially impact groundwater.

The type of groundwater action required at this time is contingent on the results of an investigation that would be conducted to determine the location and size of the remaining VOC source areas (if any) underlying the 903 Pad area. Therefore, an investigation is part of this IM/IRA. The investigation approach for determining the potential source areas is included in Appendix H. Results of the investigation will dictate the action required. However, it is expected that areas with elevated VOC concentrations will be identified. Therefore, based on previous experience at the Site with VOC sources, two

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alternatives were selected for analysis: source removal and *in-situ* enhanced bioremediation. For the purpose of the alternatives analysis, two source areas were assumed, each approximately 100 feet square, 3 feet thick, and at a depth of 15 feet.

Where observed, the downgradient contaminated groundwater is found in weathered bedrock and its presence is controlled primarily by the amount of precipitation received. Investigations over the last several years in the downgradient plume did not encounter groundwater at many locations. This indicates that the downgradient portion of this plume only has the ability to impact surface water in wet years. Recent investigations observed very few areas where seeps with potentially contaminated water could impact surface water. For these reasons, passive groundwater collection and treatment was not selected as an alternative for evaluation because there is insufficient groundwater generally present to support groundwater collection and treatment. Because of the higher installation and ongoing operational costs for a system that would only sporadically treat groundwater, this alternative is not considered feasible and was not further evaluated.

6.6.1 Source Removal

Source removal is an effective method of reducing contaminant load in the subsurface where the contaminated area can be clearly defined. VOC source removal was not conducted during the 903 Pad radiological remedial action because of the expected greater depth of the VOC contamination, and the controls required for the radiological remedial action that made deeper excavation more difficult. However, some VOC-contaminated soil was removed with the radiological contamination during this action. For additional information on these areas, see Appendix H, Figure H-1.

6.6.1.1 Effectiveness

Excavation was previously completed at the Ryan's Pit area and additional removal is not warranted. At the 903 Pad, assuming that the VOC source areas are well defined, excavation is an effective method for reducing contaminant load. Based on past experience at the Site, it is unlikely that the entire VOC source material can be removed. Small amounts generally remain in the environment, which continue to act as a long-term source of groundwater contamination. However, reduction of the source should eventually result in faster recovery of the groundwater quality in this area.

Short-term effectiveness - Dust emissions and sediment load to the streams would increase during construction that would be mitigated through standard construction practices. Release of contaminants to potentially uncontaminated areas is possible during source removal, and an increased risk to the worker from construction accidents and exposure to high concentrations of VOCs is likely. If contamination is found at increased depths, then layback of the excavation and other measures may be required to allow equipment to reach the contaminated area, creating more hazards. An area approximately 10,000 square feet would be disturbed to accommodate excavation and staging areas. However, this area is within the 903 Pad project site and already significantly disturbed. In addition, disturbing VOC source areas generally results in increasing the groundwater

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contamination in the area of the excavations. While mitigating measures would be taken, an increase in groundwater contamination concentrations is probable in the area.

Long-term effectiveness - There would be reduced contaminant mass at the source area. This reduces the risk to a future worker inadvertently disturbing the area, and would decrease the amount of time required to naturally degrade the groundwater plume at this location.

Compliance with ARARs - ARARs would generally be met with the exception of the potential to impact surface water in wet years. However, there would be a reduced contaminant mass remaining within the source area, with a decreased potential for exceeding ARARs in the future.

6.6.1.2 Implementability

This alternative would be readily implemented using standard industry equipment and practices. RAOs of reducing soil contamination that contributes to groundwater and surface water contamination would be met.

6.6.1.3 Cost

The cost of excavating a small contamination source is $300 per cubic yard based on prior experience at the Site and a depth of 15 feet or less. Waste disposal costs are an additional $700 for each cubic yard of waste that does not require treatment. For two areas measuring 15 feet deep, 100 feet square and 3 feet thick, the cost is approximately $650,000 for excavation and an additional $1,500,000 for waste disposal. No waste treatment costs were assumed at this time. However, if waste treatment is required, additional costs would be incurred. Costs would also increase if contamination is of greater extent or at greater depths. Costs for Ryan's Pit were not considered because excavation is already completed at this project site.

6.6.1.4 Summary

This alternative has high costs if the source areas are not located very close to the surface.

6.6.2 *In-Situ* Enhanced Biodegradation

As described in Table 6-2, several different types of additives can be used *in-situ* to reduce the contaminant load contributing to groundwater contamination. Amendments must be appropriately matched to the project-specific subsurface conditions and contaminants. The objective is source reduction that contributes to groundwater contamination so only the identified source areas would be treated. Residual contamination at the Ryan's Pit area will also be evaluated to determine whether treatment will reduce the residual contamination.

The amendments considered are described in Table 6-7. Because the use of oxidants has a higher worker safety risk than amendments, and oxidants tend to destroy the existing microbial community that may already be in-place degrading the contaminants, *in-situ* chemical oxidation was not further evaluated.

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Table 6-7. Common Types of Enhanced Biodegradation Amendments

Amendment Type	How it Works	Considered for Further Evaluation?
Edible oils, sugars, and other organic products	Biostimulation – These products provide nutrients and electron receptors to the existing microbes to enhance biodegradation. Types of products include milk sugar, molasses, fructose, ethanol, semi-solids such as various proprietary slow-release compounds and edible oils, and solids such as tree bark and chitin.	Yes. Selected for evaluation. These types of materials will support the local microbe population and accelerate biodegradation at these sites.
Reactive iron	Placing zero-valent iron with or without additional carbon source in the area. Creates a reducing environment and promotes microbial growth which, in turn, enhances biodegradation.	Yes. Selected for evaluation. These types of materials will support the local microbe population and accelerate biodegradation at these sites.

The specific amendment will be evaluated during project planning as required.

6.6.2.1 Effectiveness

Short-term effectiveness – One area of approximately 200 square feet would be disturbed at Ryan's Pit. In addition, two areas of approximately 500 square feet each would be disturbed at the 903 Pad. However, all areas were already significantly disturbed during remedial activities. Dust generation would be minimal because dust suppression techniques would be employed. Workers would be exposed to standard construction hazards. Most amendments are relatively non-toxic and are often of food-grade quality, posing low risk to the workers. Implementation would result in release of degradation products to the groundwater system.

Long-term effectiveness – *In-situ* enhanced biodegradation is a viable technology for groundwater remediation at Rocky Flats and has successfully been demonstrated at the PU&D Yard Plume Project to reduce contaminant load in soil where no large quantities of free product are present. HRC® is effective in reducing the contaminant load in soil that contributes to groundwater contamination. It is relatively long acting in this environment, inexpensive, and effective. Other commercially available types of amendments are anticipated to be equally effective.

Compliance with ARARs - No change in compliance with ARARs (surface water standards) is anticipated at the surface water POC on Woman Creek. However, the contaminant mass remaining within the source area would be reduced. Conditions are anticipated to be appropriate to degrade daughter products with minimal impacts to surface water.

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6.6.2.2 *Implementability*

A variety of products are commercially available and proven installation methods have been identified. After the investigation is completed, there would be sufficient data available for the 903 Pad/Ryan's Pit area to determine the appropriate product or range of products. Identification of the appropriate product would take place after the investigation is completed and during the implementation phase of the Groundwater IM/IRA.

6.6.2.3 *Cost*

The cost for the 903 Pad/Ryan's Pit Plume Project is anticipated to be approximately $300,000, and includes installation of two monitoring wells and monitoring these for one year. Additional monitoring wells are not required for the Ryan's Pit area because of the existing wells in the area. Application of the amendment would be a one-time event. Costs were based on the PU&D Yard Project and were increased to account for the larger area to be covered.

6.6.2.4 *Summary*

This alternative is relatively low cost, is easily implemented, reduces the contaminant load in the soil, and would have a positive impact on groundwater quality.

6.6.3 Preferred Alternative

Comparison of the evaluated alternatives is summarized in Table 6-8. If source areas are identified during the planned investigation, *in-situ* enhanced biodegradation is the preferred alternative. If no discrete source areas are identified, then the regulatory agencies would be consulted on the path forward.

Table 6-8. Comparison of Groundwater Remediation Alternatives for the 903 Pad/Ryan's Pit Plume

Alternative	Description	Effectiveness	Implement-ability	Comparative Cost
Source Removal	Excavation and disposal of well-defined VOC contaminated soil	Effective in reducing high volumes of contaminated soil present at source areas. Complete source removal is not possible. Increased short-term groundwater contamination often seen following actions.	High – readily implemented	High - $2,000,000
In-situ Enhanced Biodegradation	Using *in-situ* amendments to reduce contaminant mass	Effective in reducing residual contaminant load in soil and groundwater. Would not negatively impact surface water quality.	High – readily implemented	Low - $300,000

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7.0 PROJECT APPROACH

This section presents the proposed actions for each of the remedies selected in Section 6.0. Table 7-1 summarizes the project approach for each plume area. The alternatives are not intended to eliminate groundwater contamination in the source areas. Rather, alternatives were selected that reduce the source of groundwater contamination and/or reduce surface water contamination. The alternatives are relatively long-term, passive methods that would have a positive, long-term impact on groundwater or surface water quality, even if these are minimal impacts. Post-accelerated action monitoring for each remedy is presented in Section 7.7.

Table 7-1. Selected Remedy by Plume Area

Plume Area	Selected Remedy
Carbon Tetrachloride Plume (IHSS 118.1)	Soil Source Removal/ Excavation with *in-situ* Enhanced Biodegradation
Downgradient of East Trenches Plume	Phytoremediation
Downgradient of Solar Ponds Plume	Phytoremediation
Mound Site/Oil Burn Pit #2	Soil Source Removal/ Excavation with *in-situ* Enhanced Biodegradation
903 Pad/Ryan's Pit	To be determined based on investigation results. Evaluated as *in-situ* Enhanced Biodegradation

7.1 Carbon Tetrachloride Plume (IHSS 118.1)

7.1.1 Project Approach

The proposed action for this plume area is source removal in conjunction with *in-situ* enhanced biodegradation to further reduce contaminant concentrations at this location and the potential impacts to groundwater. Both source removal and *in-situ* biodegradation will take place under the ER RSOP, but are included here for completeness. The project area is shown on Figure 7-1.

7.1.1.1 Excavation

Building 730 extended approximately 21 feet below the existing ground surface within a previous excavation approximately 22 feet below ground surface and roughly 55 feet square. The original excavation was dug into the claystone bedrock and was backfilled with fill material consisting of unconsolidated clay, sand, and gravel with associated construction debris from Building 730. Up to 5,000 gallons of CT are present immediately above the bedrock claystone at the base of the previous excavation.

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Groundwater sumps were maintained during the excavation to keep the groundwater level below the Arapahoe No. 1 Sandstone located immediately east of Building 730 and exposed in the sides of the previous excavation. This unit could act as a preferential pathway for groundwater contamination to spread during excavation activities.

The soil excavation was sloped to allow equipment access to the lowermost structures and contamination. An excavator was used to remove the soils. The remediation goal was to remove soils contaminated with free CT liquid. Soils below WRW ALs were stockpiled at the project site for later use as backfill. Removed soils above ALs were placed in appropriate waste containers.

The walls and Building 730 contents were size-reduced in-place, then loaded from the excavation into intermodals and waste crates for off-site disposal. Associated utilities were removed and appropriately dispositioned. A number of process waste lines associated with Building 730 were also excavated, removed and dispositioned as part of this project. These were dispositioned in accordance with the ER RSOP Notification #03-14 for IHSS Group 000-2, Original Process Waste Lines (OPWLs) (DOE, 2003a).

The Building 730 slab was within the zone of CT free product. Prior to removing this structure, as much of the free product as possible was removed from the excavation. After removal of the free product, the part of the slab beneath the southern, more contaminated tanks was size-reduced and packaged in waste crates along with the associated contaminated soil. The less contaminated northern part of the slab was left in-place. Following removal of the structures, soil excavation continued until visible free product was removed.

During soil handling activities that result in dust generation, dust minimization techniques, such as water sprays, were used to minimize suspension of particulates. In addition, excavation operations were not conducted during periods of sustained high winds. The RFETS Environmental Restoration Field Operations Procedure FO.01, Air Monitoring and Dust Control, was followed.

Building 730 and its contents were radiologically contaminated. However, the soil is not radiologically contaminated, and no radiological soil sampling was required except to verify final project conditions prior to backfill. All equipment was monitored prior to leaving the site, and work was evaluated during the project to determine whether radiological monitoring was required. All monitoring was in accordance with 10 CFR 835 and the RFETS Radiological Controls Manual (K-H, 1996b). When unexpected hazards or conditions were encountered during remediation, work was halted in order to re-evaluate the existing procedures to ensure they were safe and appropriate.

7.1.1.2 Backfill and In-Situ *Enhanced Biodegradation*

After the remedial action was completed at this site, a railroad spur (to be used for waste shipment) was constructed at this location. Final regrading and revegetation will not occur until after use of the railroad is discontinued.

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After contaminated soil excavation was complete, the excavation was backfilled with the stockpiled soils and additional fill dirt as required. HRC-X, an amendment used for *in-situ* enhanced biodegradation was placed in the excavation at the depths where contaminated soils were still present.

HRC-X is an extended-life product and application will be a one-time event. As described in Section 6.0, the material is anticipated to boost the production of resident microbes that would effectively reduce the amount of residual VOC contamination remaining at this project site.

7.1.2 Long-Term Maintenance

No long-term maintenance of the action is anticipated except for monitoring as described in Section 7.7. Application of the soil amendment was a one-time event.

7.1.3 Worker Safety

A Site-specific Health and Safety Plan (HASP) was developed to address the safety and health hazards of project operations and specify the requirements and procedures for employee protection. The Occupational Safety and Health Administration (OSHA) construction standard for Hazardous Waste Operations and Emergency Response, 29 Code of Federal Regulations (CFR) 1926.65 was used as the basis for the HASP. In addition, DOE Order 5480.9A, Construction Project Safety and Health Management, applies to this project. This order requires preparation of Job Hazard Analyses (JHAs) to identify each task, hazards associated with each task, and controls necessary to eliminate or mitigate the hazards. The JHAs were included in the HASP.

This project potentially exposed workers to physical, chemical, and low levels of radiological hazards. The physical hazards include those associated with excavation activities, use of heavy equipment, noise, heat stress, cold stress, and work on uneven surfaces. Physical hazards were mitigated by appropriate use of personal protective equipment (PPE), engineering, and administrative controls. Chemical hazards were mitigated by the use of PPE and administrative controls. Appropriate skin and respiratory PPE were worn throughout the project. Routine VOC monitoring was conducted with an organic vapor monitor for any employees who must work near the contaminated soil (i.e., soil sampling or excavation personnel). Based on employee exposure evaluations, the Site Health and Safety Officer was able to downgrade PPE requirements, if appropriate.

A project specific radiological work permit was developed for this project because of the planned Building 730 removal. The HASP also included project "hold points," which accounted for unanticipated hazards such as contaminated debris. Radiation monitoring was included as appropriate to meet this approach in the HASP per the RFETS Radiological Controls Manual (K-H, 1996b).

If field conditions varied from the planned approach, a JHA was prepared for the new conditions, and work proceeded according to the appropriate control measures. Data and controls were continually evaluated. Field radiological screening was conducted using

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radiological instruments appropriate to detect surface contamination and airborne radioactivity. As required by 10 CFR 835, Radiation Protection of Occupational Workers, applicable RFETS implementing procedures would be followed to ensure protection of the workers, co-located workers, the public, and the environment. The HASP described the air monitoring equipment and methods to be used to monitor for VOCs, particulates, and radiation. Finally, dust minimization techniques were used to minimize suspension of contaminated soils.

7.1.4 Waste Management

When the excavation for the Building 730 was performed, soil with concentrations below soil ALs was stockpiled at the project site for use as backfill. Water accumulating during excavation was pumped to a portable water tank, then pumped to a tank or tanker truck for transport to and treatment in the Consolidated Water Treatment Facility. Any associated collected sediment was segregated, sampled as necessary, and appropriately dispositioned.

Concrete was disposed as low-level waste up to the point of contact with free CT. This concrete would be dispositioned as low-level mixed waste and will require treatment, expected to be encapsulation, at an off-site treatment facility. Any removed CT in liquid form was packaged and is expected to be shipped off-site for treatment, most likely incineration. Soils contaminated with high levels of CT are expected to be either treated off-site by incineration, oxidation, or thermal desorption, or on-site by thermal desorption.

7.2 Downgradient Portion of the East Trenches Plume

A source removal was completed for Trenches T-3 and T-4 in 1996, and a 1,200-foot-long passive groundwater collection and treatment system was installed in 1999. However, a portion of the plume is located north of the groundwater collection system and is not being intrecepted. This portion of the plume impacts surface water above SWPRGs. The location is roughly defined as the area north of the B-Series ponds access road and south of South Walnut Creek, including Ponds B-1, B-2, and B-3. The proposed action is to incorporate phytoremediation in the area between the access road and the B-Series ponds in the portion of the groundwater plume downgradient of the East Trenches Plume Collection system (Figure 7-2).

7.2.1 Project Approach

The downgradient portion of the East Trenches Plume would be planted with deep-rooted native tree species to intercept the shallow groundwater. The final selection of the species that would be planted would be made during the implementation of the remedy. All candidate species are in the willow family (*Salicaceae*), which includes the genus *Populus*, known to be effective in phytoremediation applications, including the removal of organic contaminants. At least six species of poplars, cottonwoods, and willows are found at RFETS that may be suitable for phytoremediation.

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The specific number of plantings for the East Trenches area will be determined based on the site characteristics. The planting density would take into consideration that some saplings will not survive, but still allow for a sufficient number of surviving saplings to provide adequate remediation. The estimated area for the East Trenches project is approximately 2.5 acres. Figure 7-2 shows the proposed planting area.

The initial installation would use whips or bare-root saplings. Whips would be acquired from the nursery in 8- to 10-foot lengths, a suitable length for a phytoremediation installation. To promote rapid growth and deep-rooting, the whips would be planted up to 6 feet deep. Planting would be accomplished with mechanical means, whereever possible and as site conditions allow. A drill rig, Geoprobe equipped with an auger, backhoe equipped with a small diameter auger, or similar equipment would be used to excavate the planting holes. The use of soil amendment would be minimized to encourage the plants to adapt to the existing conditions, but some soil augmentation may be needed to ensure the plantings take hold.

Timing is critical for a successful phytoremediation project. The growers have to be prepared to supply the requisite number of trees in time for planting. Poplars would be harvested in the late fall or early spring, and may be stored for a short period of time until needed. For this project, an early spring harvest and planting are proposed. Once this approach is approved, procurement would commence immediately to ensure that adequate nursery stock is available to meet planting requirements.

While much of the project area is mesic, some of the trees would be in drier soil, requiring irrigation for the first year after installation. Drip irrigation would be installed where necessary and would use water supplied from a portable storage tank sized to provide water for several days between fillings during peak-demand weather. The irrigation system would be a surface installation to facilitate removal once the irrigation system is no longer needed. The plantings would be monitored for health and vigor. However, replacements will not be made in areas where sufficient groundwater is not available to sustain vegetation. Replacements will only be made in the first year to replace obviously diseased or damaged trees. Once established, the trees would be able to subsist on the groundwater; in fact, irrigation is not recommended after this initial period in order to encourage the tree roots to grow deeply.

7.2.2 Long-Term Maintenance

No long-term maintenance of the action is anticipated except for monitoring as described in Section 7.7. Irrigation would not continue past the first year, and natural attrition would be allowed to occur where sufficient groundwater cannot sustain vegetation.

7.2.3 Worker Safety

A Site-specific HASP would be developed to address the safety and health hazards of project operations and to specify the requirements and procedures for employee protection. The OSHA construction standard for Hazardous Waste Operations and Emergency Response, 29 CFR 1926.65 would be used as the basis for the HASP. In addition, DOE Order 5480.9A, Construction Project Safety and Health Management,

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applies to this project. This order requires preparation of JHAs to identify each task, hazards associated with each task, and controls necessary to eliminate or mitigate the hazards. The JHAs would be included in the HASP.

This project could potentially expose workers to physical hazards. The physical hazards include those associated with augering activities, use of heavy equipment, noise, heat stress, cold stress, and work on uneven surfaces. Physical hazards would be mitigated by appropriate use of PPE, engineering, and administrative controls. The HASP also would include project "hold points," which would account for unanticipated hazards such as contaminated debris. Radiation monitoring would be included as appropriate to meet this approach in the HASP per the RFETS Radiological Controls Manual (K-H, 1996b).

If field conditions vary from the planned approach, a JHA would be prepared for the new conditions, and work would proceed according to the appropriate control measures. Data and controls would be continually evaluated. Field radiological screening would be conducted using radiological instruments appropriate to detect surface contamination and airborne radioactivity. As required by 10 CFR 835, Radiation Protection of Occupational Workers, applicable RFETS implementing procedures would be followed to ensure protection of the workers, collocated workers, the public, and the environment. Finally, dust minimization techniques would be used to minimize suspension of soil.

7.2.4 Waste Management

All soil excavated for tree planting is anticipated to contain contaminant concentrations below soil ALs. Excess soil would be spread in the general vicinity of the planting area. Only small volumes of other waste, such as the root ball covers, string, irrigation piping, and miscellaneous construction materials would be generated and disposed of as sanitary waste.

7.3 Downgradient Portion of the Solar Ponds Plume

A portion of the SPP is located downgradient of the collection system and continues to persist. The area of highest groundwater contamination within the residual plume is immediately adjacent and downgradient of the previous sump and pump house for the ITS that drained this hillside prior to installation of the Solar Ponds Plume Collection System. The SPP treatment system discharge gallery is also located adjacent to North Walnut Creek. The highest nitrate values are found within this area in an area approximately 200 feet square immediately adjacent to North Walnut Creek (Figure 7-3). The proposed action is to incorporate phytoremediation in the area of the discharge gallery and along North Walnut Creek eastward.

7.3.1 Project Approach

The downgradient portion of the SPP would be planted with deep-rooted native tree species to intercept the shallow groundwater. As described above, the selection of the species would be made during the implementation of this action. The same species selected for the East Trenches Plume supplement would be used in the SPP area. In addition to the capability to remove organic contamination, the ability of *Populus* species

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to take up nitrate is well established; some research reports up to 99% removal of nitrate from contaminated groundwater.

The specific number of plantings for the SPP area will be determined based on the site characteristics. The planting density would take into consideration that some saplings will not survive, but will still allow for a sufficient number of surviving saplings to provide adequate remediation. The planted area would center on the current discharge gallery as shown on Figure 7-3, where the highest groundwater concentrations of nitrate are known to occur.

The initial installation would use whips or saplings. Whips would be acquired from the nursery in 8- to 10-foot lengths, a suitable length for a phytoremediation installation. To promote rapid growth and deep-rooting the whips are planted up to 6 feet deep. Planting would be accomplished with mechanical means, wherever possible, and as Site conditions allow. A backhoe equipped with a small diameter auger or similar equipment would be used to excavate the planting holes. The use of soil amendment would be minimized to encourage the plants to adapt to the existing conditions; however, some soil augmentation may be needed to ensure the plantings take hold.

Timing is critical for a successful phytoremediation project. The growers have to be prepared to supply the requisite number of trees in time for planting. Poplars would be harvested in the late fall or early spring, and may be stored for a short period of time until needed. For this project, an early spring harvest and planting are proposed. Once this approach is approved, procurement would commence immediately to ensure that adequate nursery stock is available to meet planting requirements.

While much of the project area is mesic, some of the trees would be in drier soils, requiring irrigation for the first year after installation. Drip irrigation would be installed where necessary and would use water supplied from a portable storage tank sized to provide water for several days between fillings during peak-demand weather. The irrigation system would be a surface installation to facilitate removal once the irrigation system is no longer needed. The plantings would be monitored for health and vigor. However, replacements will not be made in areas where sufficient groundwater is not available to sustain vegetation. Replacements will only be made in the first year to replace obviously diseased or damaged trees. Once established, the trees would be able to subsist on the groundwater; in fact, irrigation is not recommended after this initial period in order to encourage the tree roots to grow deeply.

7.3.2 Long-Term Maintenance

No long-term maintenance of the action is anticipated except for monitoring as described in Section 7.7. Irrigation would not continue past the first year, and natural attrition would be allowed to occur where sufficient groundwater cannot sustain vegetation.

7.3.3 Worker Safety

A Site-specific HASP would be developed to address the safety and health hazards of project operations and to specify the requirements and procedures for employee

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protection. The OSHA construction standard for Hazardous Waste Operations and Emergency Response, 29 Code of Federal Regulations (CFR) 1926.65 would be used as the basis for the HASP. In addition, DOE Order 5480.9A, Construction Project Safety and Health Management, applies to this project. This order requires preparation of JHAs to identify each task, hazards associated with each task, and controls necessary to eliminate or mitigate the hazards. The JHAs would be included in the HASP.

This project could potentially expose workers to physical hazards. The physical hazards include those associated with augering activities, use of heavy equipment, noise, heat stress, cold stress, and work on uneven surfaces. Physical hazards would be mitigated by appropriate use of PPE, engineering, and administrative controls. The HASP also would include project "hold points," which would account for unanticipated hazards such as contaminated debris. Radiation monitoring would be included as appropriate to meet this approach in the HASP per the RFETS Radiological Controls Manual (K-H, 1996b).

If field conditions vary from the planned approach, a JHA would be prepared for the new conditions, and work would proceed according to the appropriate control measures. Data and controls would be continually evaluated. Field radiological screening would be conducted using radiological instruments appropriate to detect surface contamination and airborne radioactivity. As required by 10 CFR 835, Radiation Protection of Occupational Workers, applicable RFETS implementing procedures would be followed to ensure protection of the workers, co-located workers, the public, and the environment. Finally, dust minimization techniques would be used to minimize suspension of soil.

7.3.4 Waste Management

All soils excavated for tree planting are anticipated to have contaminant concentrations below soil ALs. Excess soils would be spread in the general vicinity of the planting area. Only small volumes of other waste such as the root ball covers, string, irrigation piping, and miscellaneous construction materials would be generated and disposed of as sanitary waste.

7.4 Mound Site/Oil Burn Pit #2 Plume

As described in Section 6.0, a soil removal action would be performed under the ER RSOP to remediate the PCB contamination in the subsurface at the Oil Burn Pit #2. This action would also reduce the amount of VOC contamination present at this project site. Amendments would then be used to promote *in-situ* enhanced biodegradation to reduce the residual contamination at Oil Burn Pit #2 (Figure 7-4). At this location, there is an area of approximately 2,000 square feet that contains the highest concentrations of VOCs, primarily PCE and TCE at depths of 2.5 to 10 feet below ground surface. PCE is the predominant contaminant with concentrations up to 27,000 mg/kg. TCE occurs at concentrations up to 3,700 mg/kg. PCBs also occur at this location, but are not impacting groundwater.

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7.4.1 Project Approach

An area approximately 10 feet by 10 feet by 10 feet deep would be remediated using an excavator. The soil excavation would be sloped to allow equipment access to safely access the lowermost contamination. An excavator would be used to remove the soils. The remediation goal would be to remove PCB contamination above WRW ALs. Soil with contaminant concentrations below WRW ALs would be stockpiled at the project site for later use as backfill. Removed soils above ALs would be placed in appropriate waste containers.

During soil handling activities that result in dust generation, dust minimization techniques, such as water sprays, would be used to minimize suspension of particulates. In addition, excavation operations would not be conducted during periods of sustained high winds. The RFETS Environmental Restoration Field Operations Procedure FO.01 - Air Monitoring and Dust Control would be followed.

An amendment would be selected during the project implementation phase based on the project specific conditions. Application of the appropriate amendment would be based on manufacturer's recommendations but is anticipated to occur at regularly spaced intervals throughout the identified source area. It is anticipated that the materials would be added with the backfill within the excavation area, and inserted into the subsurface through geoprobe holes in the rest of the area, similar to the PU&D Yard Plume Treatability Study (K-H, 2001c). In general, this process would involve geoprobing at designated locations to a depth of 10 feet below ground surface, placing the amendment into the hole over the full length, then capping the hole with bentonite. The amount of amendment used would be developed with the manufacturer's guidance based on the project-specific parameters.

Application of the amendments would be a one-time event and is not intended to eliminate the source of groundwater contamination entirely. Insertion of amendments into the downgradient plume is not planned. The amendments are not considered as effective in reducing the dissolved-phase contaminants in the plume because of the lower contaminant quantities and larger volumes of water, requiring larger populations of bacteria to be present. However, use of *in-situ* enhanced biodegradation would reduce the amount of source material present that contributes to groundwater contamination.

7.4.2 Long-Term Maintenance

Except for the continued long-term maintenance of the Mound Plume Treatment System as described in the Mound Plume Decision Document (DOE, 1997a), no additional long-term maintenance of the action is anticipated except for monitoring described in Section 7.7. Application of the soil amendments would be a one-time event. As described in Section 6.0, the material is anticipated to boost the production of resident microbes that would effectively reduce the amount of residual contamination remaining at this project site.

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7.4.3 Worker Safety

A Site-specific HASP would be developed to address the safety and health hazards of project operations and to specify the requirements and procedures for employee protection. The OSHA construction standard for Hazardous Waste Operations and Emergency Response, 29 CFR 1926.65 would be used as the basis for the HASP. In addition, DOE Order 5480.9A, Construction Project Safety and Health Management, applies to this project. This order requires preparation of JHAs to identify each task, hazards associated with each task, and controls necessary to eliminate or mitigate the hazards. The JHAs would be included in the HASP.

This project could potentially expose workers to physical hazards. The physical hazards include those associated with geoprobe activities, use of heavy equipment, noise, heat stress, cold stress, and work on uneven surfaces. Physical hazards would be mitigated by appropriate use of PPE, engineering, and administrative controls. The HASP would also include project "hold points," which would account for unanticipated hazards. Radiation monitoring would be included as appropriate to meet this approach in the HASP per the RFETS Radiological Controls Manual (K-H, 1996b).

If field conditions vary from the planned approach, a JHA would be prepared for the new conditions, and work would proceed according to the appropriate control measures. Data and controls would be continually evaluated. Field radiological screening would be conducted using radiological instruments appropriate to detect surface contamination and airborne radioactivity. As required by 10 CFR 835, Radiation Protection of Occupational Workers, applicable RFETS implementing procedures would be followed to ensure protection of the workers, collocated workers, the public, and the environment. Finally, dust minimization techniques would be used to minimize suspension of soil.

7.4.4 Waste Management

Excavated soil contaminated above soil ALs would be dispositioned as PCB waste. Soil below ALs would be stockpiled at the project site for use as backfill. Water that accumulates during excavation would be pumped to a portable water tank, then pumped to a tank or tanker truck for transport to and treatment in the Consolidated Water Treatment Facility. Any associated collected sediment would be segregated, sampled as necessary, and appropriately dispositioned.

Small volumes of sanitary waste would be generated, such as the amendment containers. The decontamination process also would generate small volumes of water that would be treated on-Site.

7.5 903 Pad/Ryan's Pit Plume

As described in Section 6.6.3, amendments to promote *in-situ* enhanced biodegradation would be used to reduce the residual contamination at Ryan's Pit that would remain after completion of the remedial action. At this location, groundwater contamination includes CT, CF, PCE and TCE. The residual contamination is located near the south side of the previously excavated area and is approximately 500 square feet.

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As described in Section 6.6 and Appendix H, an investigation would be conducted to determine the location and size of any remaining VOC source areas underlying the 903 Pad area. The determination of any required remedial action would occur after the investigation is completed and would be based on contaminant extent and concentrations in the soil and groundwater, depth to the bedrock surface and slope, and the groundwater flow direction. For the purposes of this evaluation, however, the following approach was developed for comparison purposes based on the assumption that the investigation would locate source areas that are amenable to treatment using *in-situ* enhanced biodegradation. The plume area with representative remediation areas is shown on Figure 7-5.

7.5.1 Project Approach

An amendment would be selected during the project implementation phase based on the project-specific conditions. Application of the appropriate amendment would be based on manufacturer's recommendations but is anticipated to occur at regularly spaced intervals throughout the identified source area. It is anticipated that the materials would be inserted into the subsurface through geoprobe holes. In general, this process would involve geoprobing at designated locations to a depth that includes the contaminated interval, placing the amendment into the hole so that the full length of the contaminated interval is covered by the amendment, then backfilling the remainder of the hole with bentonite. The amount of amendment used would be calculated with the manufacturer's guidance based on the project specific parameters.

One source area approximately 200 feet square is present at Ryan's Pit. Using the example provided in Section 6.6.2.1, two source areas were assumed to be present at the 903 Pad; each about 100 feet square, 3 feet thick and at a depth of 15 feet. The geoprobe holes would be placed at regularly spaced intervals across each area to a depth of 15 feet, the amendment would be added to each hole to cover the contaminated zone by at least one foot, then the remainder of the hole would be backfilled with bentonite.

Application of the amendments would be a one time event and is not intended to eliminate the source of groundwater contamination entirely. Insertion of amendments into the downgradient plume is not planned. The amendments are not considered as effective in reducing the dissolved phase contaminants in the plume because of the lower contaminant quantities and larger volumes of water, requiring larger populations of bacteria to be present. However, use of *in-situ* enhanced biodegradation would reduce the amount of source material present that contributes to groundwater contamination.

7.5.2 Long-Term Maintenance

No long-term maintenance of the action is anticipated except for monitoring as described in Section 7.7. pplication of the soil amendments would be a one time event. As described in Section 6.2.2, the material is anticipated to boost the production of resident microbes that would effectively reduce the amount of residual contamination remaining at this project site.

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7.5.3 Worker Safety

A Site-specific HASP would be developed to address the safety and health hazards of project operations and to specify the requirements and procedures for employee protection. The OSHA construction standard for Hazardous Waste Operations and Emergency Response, 29 Code of Federal Regulations (CFR) 1926.65 would be used as the basis for the HASP. In addition, DOE Order 5480.9A, Construction Project Safety and Health Management, applies to this project. This order requires preparation of JHAs to identify each task, hazards associated with each task, and controls necessary to eliminate or mitigate the hazards. The JHAs would be included in the HASP.

This project could potentially expose workers to physical hazards. The physical hazards include those associated with geoprobe activities, use of heavy equipment, noise, heat stress, cold stress, and work on uneven surfaces. Physical hazards would be mitigated by appropriate use of PPE, engineering, and administrative controls. The HASP would also include project "hold points," which would account for unanticipated hazards. Radiation monitoring would be included as appropriate to meet this approach in the HASP per the RFETS Radiological Controls Manual (K-H, 1996b).

If field conditions vary from the planned approach, a JHA would be prepared for the new conditions, and work would proceed according to the appropriate control measures. Data and controls would be continually evaluated. Field radiological screening would be conducted using radiological instruments appropriate to detect surface contamination and airborne radioactivity. As required by 10 CFR 835, Radiation Protection of Occupational Workers, applicable RFETS implementing procedures would be followed to ensure protection of the workers, collocated workers, the public, and the environment. Finally, dust minimization techniques would be used to minimize suspension of soil.

7.5.4 Waste Management

No soil waste is anticipated to be generated by this activity. Small volumes of sanitary waste would be generated such as the amendment containers. In addition, the decontamination process would generate small volumes of water that would be treated on-Site.

7.6 Potential Additional Actions

Groundwater quality is expected to slowly respond to the actions implemented and will not improve significantly in the short-term (i.e., within a few years). Long-term data evaluation and trending will be used to provide a timely mechanism for making decisions related to changes in the observational monitoring data collected in accordance with the monitoring described in Section 7.7. The trend analysis will be used to determine where progress toward a favorable conclusion to the remedial process is occurring, or indicate plumes where RAOs may no longer be met.

If the data trend over several years indicates that RAOs will not be met, then additional potential actions would be evaluated either for the existing actions or for plumes without current actions. If there are consistent indicators of increasing trends or impact to surface

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water, the Site will consult on a course of action, as appropriate. If the trend is not consistent, then continued observation will be the most appropriate response. The potential course of action in each case would be determined in consultation with the regulatory agencies and may include any of the actions described in the alternatives analysis, such as insertion of amendments (or additional amendments), source removal, or phytoremediation.

7.7 Performance Monitoring

Performance monitoring, which will consist of both groundwater and surface water monitoring (in Ponds B-3 and B-4), will evaluate effectiveness of accelerated actions as part of a Site-wide water monitoring program. The monitoring identified here does not include the current groundwater treatment systems but does evaluate residual contamination downgradient of existing systems. This is summarized in the IMP.

Five groundwater plumes will be monitored as part of a proposed remedy.

- The CT Plume near Building 771 (in the vicinity of IHSS 118.1);
- Downgradient of the East Trenches Plume Collection System (in the South Walnut Creek drainage);
- Downgradient of the SPP Collection System;
- The Mound Site/Oil Burn Pit #2 (east of Building 991 in South Walnut Creek); and
- The 903 Pad/Ryan's Pit Plume (in the Woman Creek drainage).

A summary of the performance monitoring is provided in Table 7-2, and the proposed locations are shown on Figure 7-6. The proposed performance monitoring does not include monitoring at the Present and Original Landfills which will be outlined in separate RFCA Decision Documents. Implementation details are provided in the FY05 IMP.

Table 7-2. Groundwater Performance Monitoring Locations and Analytes

Plume Description	Performance Monitoring Location(s)[1]	Performance Monitoring Analyte(s)[2,3]
Carbon Tetrachloride Plume (118.1)	Wells 1986, 20298, 18199, and 20798	VOCs
Downgradient of East Trenches Plume Collection System	Ponds B-3 and B-4; wells 23296, TH046992, and 95199	VOCs

(table continued)

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(Table 7-2 continued)

Plume Description	Performance Monitoring Location(s)[1]	Performance Monitoring Analyte(s)[2,3]
Downgradient of Solar Ponds Plume Collection System	Wells B210489 and 1386	Nitrate and uranium
Mound Site/Oil Burn Pit #2	Wells 2187, 91203, and 15699	VOCs
903 Pad/ Ryan's Pit	Wells 90399, 90299, and 07391	VOCs

Notes:
[1]This monitoring does not include performance monitoring for the existing groundwater treatment systems.
[2]The frequency of monitoring is stipulated in the FY05 IMP.
[3]Additional analytes are monitored in the FY05 IMP, and field parameters are collected to determine the representativeness of samples.

The analytes to be measured at performance monitoring locations were determined on a plume-by-plume basis. The area downgradient of the SPP Collection System will be analyzed for nitrate and uranium. All other monitoring locations will be analyzed for VOCs. The surface water monitoring in South Walnut Creek (Ponds B-3 and B-4 for downgradient of the East Trenches Plume) will also initially be conducted on a twice-annual basis (at the same time as the groundwater monitoring sampling is conducted) unless unexpected conditions arise. Details on the water monitoring program are provided in the FY05 IMP.

7.8 Long-Term Stewardship Considerations

The objective of this section is to identify additional post-action care (that is, long-term stewardship) requirements of the proposed accelerated action for RFETS groundwater. These requirements are necessary for the long-term effectiveness of this remedy and include the following components: information management, periodic review, and maintenance of a responsible controlling authority.

Additionally, these requirements will ultimately be captured (along with post-closure care requirements from other accelerated actions at Rocky Flats) in post-closure regulatory documents, which may include the final Corrective Action Decision/Record of Decision (CAD/ROD) for Rocky Flats, any post-closure RFCA-type agreement, and any post-closure RCRA permit or other enforceable mechanism. DOE and CDPHE have not reached agreement as to whether a post-closure permit (or, alternatively, an enforceable document as defined in 6 Code of Colorado Regulations [CCR] 1007-3, Section 100.10[d]) will be required for Rocky Flats, and, if so, what requirements that permit (or enforceable document) will contain. The Parties will endeavor to resolve this matter. Failing an agreed-upon resolution, each Party reserves its rights as provided in RFCA Part 18.

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7.8.1 Information Management

A successful stewardship program is dependent on retaining the necessary records about the history and residual contamination of the site. Retained information should include the history of the site, groundwater data for the AOIs, the selected remedies, the use of controls and their associated monitoring and maintenance records, and any other information judged necessary for succeeding generations to understand the nature and extent of the residual contamination. At a minimum, the following records will be retained, stored, and retrievable for this accelerated action:

- This IM/IRA and any future modifications;
- The final design for the action and field change requests;
- The post-action drawings of the area;
- The monitoring and maintenance manual (as needed) and subsequent revisions;
- Inspection records and logbooks;
- Maintenance records and logbooks;
- CERCLA periodic review reports;
- Correspondence between the regulatory agencies associated with modifications to the post-action care regime;
- The Memorandum of Understanding (MOU) between DOE and the U.S. Department of Interior (DOI) identifying the controlling authority;
- The CAD/ROD;
- The RFETS HRR and other relevant historical documentation; and
- The Closeout Report.

This information will be maintained in the Administrative Record (AR) file (See Section 10.0). Currently, a hard copy of the AR file is maintained onsite. DOE is currently looking at options for retaining hard copies of permanent records following Site closure.

7.8.2 Periodic Assessments

Periodic assessments are performed to determine whether the selected remedies and stewardship controls continue to operate as designed, and ascertain whether new technologies might exist to eliminate remaining residual contamination in a safe and cost-effective manner. The CERCLA five-year review process is required for all Superfund sites that leave residual contamination behind after closure, and will establish the minimum requirements for post-closure periodic assessments. EPA's Comprehensive Five-Year Review Guidance (EPA, 2001) describes the format of the review and suggests

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mechanisms that can be implemented through the five-year review process to ensure the protectiveness of the remedy.

DOE is responsible for conducting the five-year reviews. EPA then issues a finding of concurrence or nonconcurrence. The public has indicated an interest in performing reviews more frequently than the five-year interval specified in CERCLA. DOE intends to work with its stakeholders to arrive at a review regimen that meets community needs.

The periodic assessment will include actions such as evaluating monitoring and maintenance records, verifying regulatory compliance, and determining whether land use assumptions are still valid. One specific topic for the periodic assessment for the area is likely to be continuance of surface water quality performance monitoring. Determining when specific types and locations of monitoring are no longer required will be part of this assessment.

7.8.3 Controlling Authority

Long-term protection of human health and the environment necessitates that a controlling authority be established with responsibility for post-closure management. CERCLA mandates that DOE, as a responsible party, will retain responsibility for the contamination at RFETS resulting from its activities there, as well as responsibility for long-term maintenance of any remedies. The Rocky Flats National Wildlife Act of 2001 requires that, following certification by EPA, once the cleanup and closure of Rocky Flats has been completed, certain lands of the current Site will be transferred from the Secretary of the Interior. These lands would be under administrative jurisdiction of the USFWS. The Act also requires the Secretary of Energy to retain administrative jurisdiction of certain real property and facilities, including engineered structures, required to carry out response actions required for the cleanup and closure of the Site. The MOU currently being negotiated between DOE and DOI will outline this process, although it is unlikely the final boundaries of the land to be transferred will be determined until the final cleanup and closure plans are approved.

7.9 Implementation Schedule

Work is anticipated to start in the first quarter of calendar year 2005 and be completed approximately six months later. These actions are expected to be the final actions for groundwater at the Site. The schedule is not an enforceable part of this IM/IRA, and DOE or its contractor may alter the schedule without prior notification to or approval by the Lead Regulatory Agency (LRA). Significant schedule changes will be shared with the LRA as part of the RFCA consultative process.

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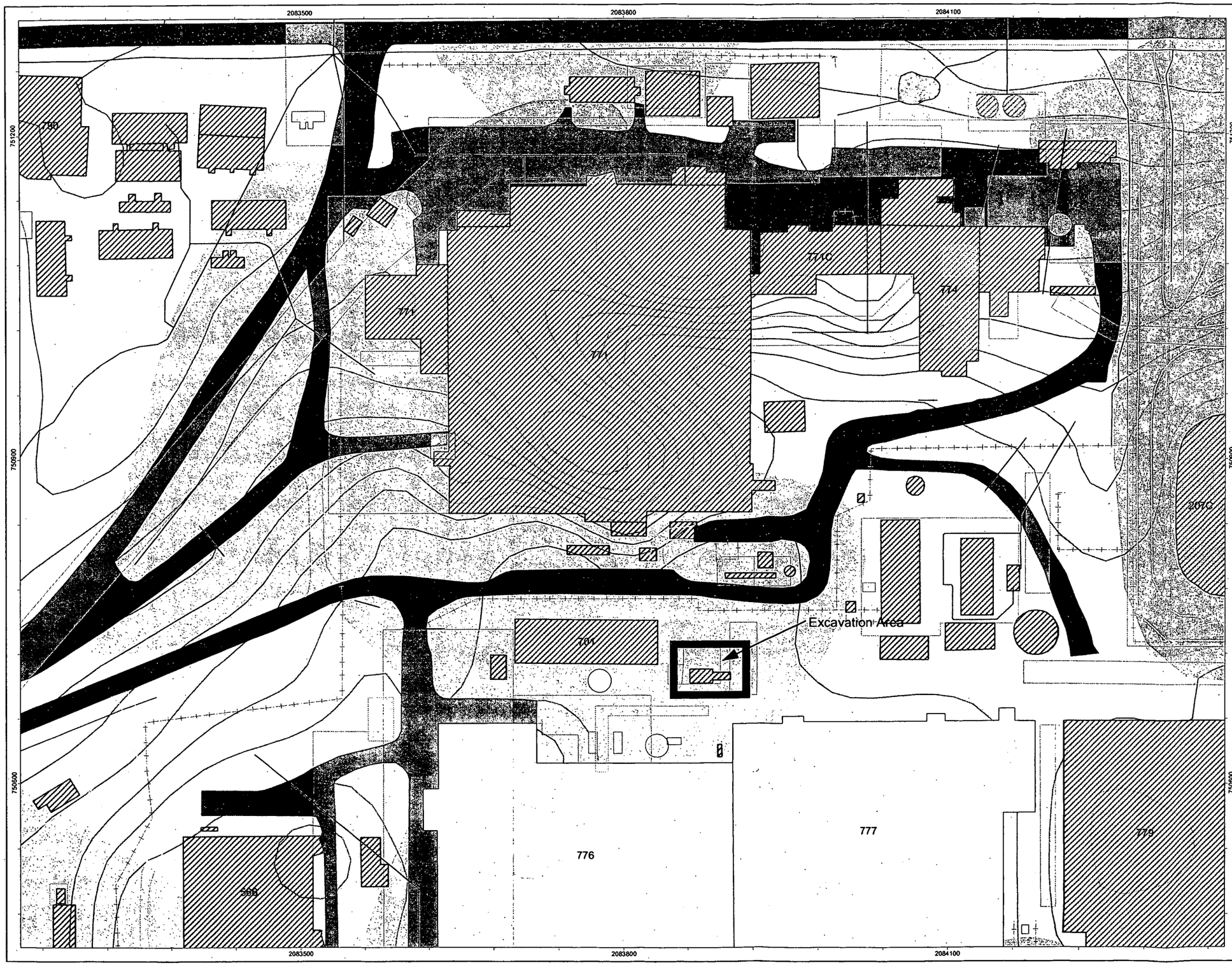

Rocky Flats Environmental Technology Site

Figure 7-1

Proposed Action at Carbon Tetrachloride Plume (IHSS 118.1)

- Proposed Phyto Remediation
- Contours
- Dirt Roads
- Trails
- Fence
- Streams
- IA OU Boundary
- Demolished Structure
- Standing Structure
- Paved Surface
- Lake
- Individual Hazardous Substance Site
- Under Building Contamination
- Potential Area of Concern
- No Further Action PACs in 1992
- Composite VOC Plume
- Nitrate Plume

N W E S

1:1,033

1 inch equals 86 feet

0 30 60 90 120 150 Feet

State Plane Coordinate Projection
Colorado Central Zone (3476)
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared By: CH2MHILL

Prepared For: KAISER•HILL COMPANY

MAP ID: GIS Dept. (303) 966-7707 June 23rd, 2004

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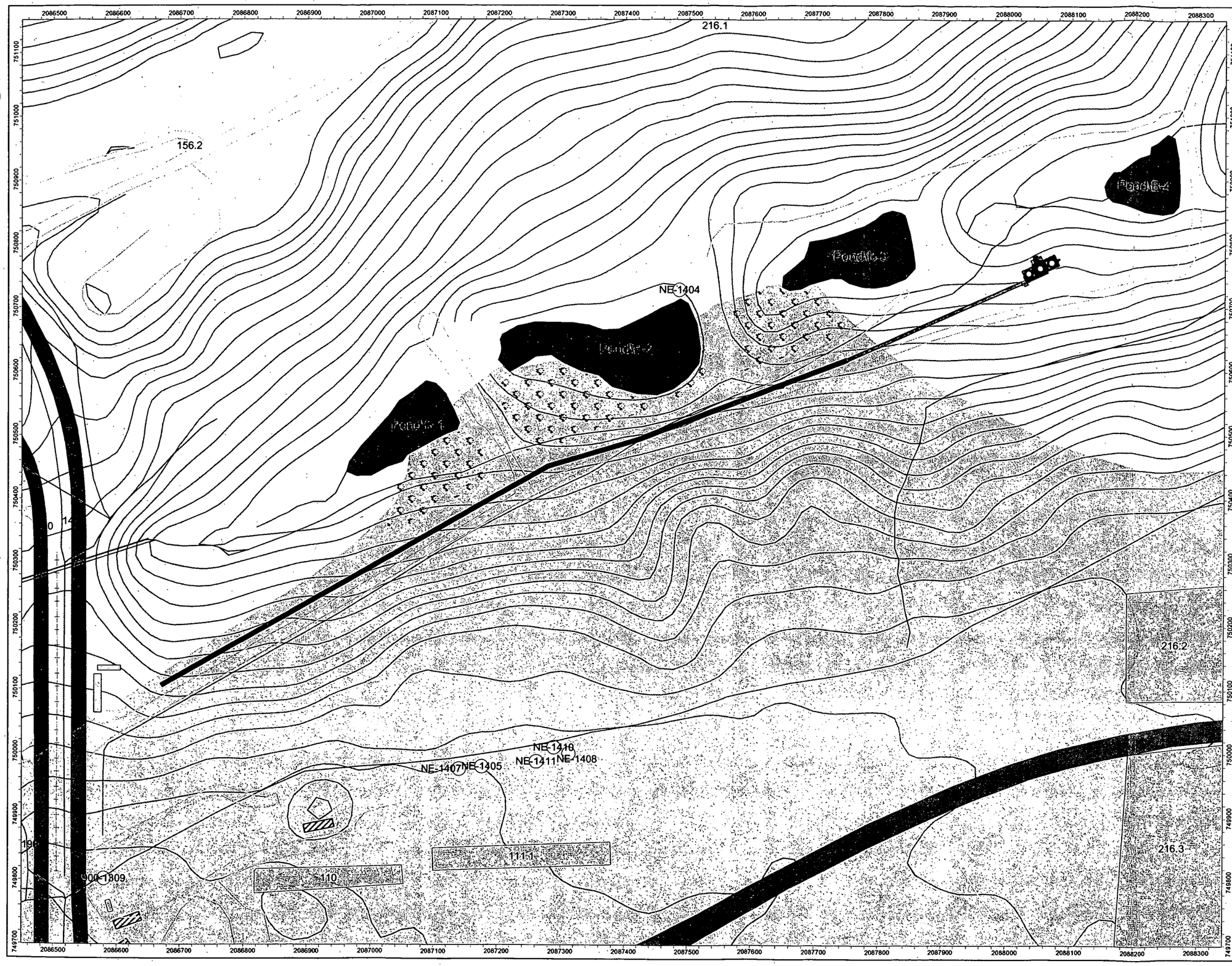
186



Rocky Flats Environmental Technology Site

Figure 7-2

Proposed Action at the East Trenches Plume

- Proposed Phyto-remediation

Treatement Infrastructure

- Transmission Pipe
- Treatement Cell
- Future Cell
- Trreatement Cell Pad
- Treatment Cell Pipe
- Other Equipment
- Collection Trench
- Former OU2 IHSS
- Potential Area of Concern
- No Further Action PACs in 1992
- Under Building Contamination
- Composite VOC Plume
- Contours
- Dirt Roads
- Trails
- Streams
- Fence
- Demolished Structure
- Standing Structure
- Paved Surface
- Ponds

N W E S

1:1,747

1 inch equals 150 feet

0 30 60 120 180 240 Feet

State Plane Coordinate Projection
Colorado Central Zone (3476)
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared By: CH2MHILL

Prepared For: KAISER•HILL COMPANY

MAP ID: GIS Dept. (303) 966-7707 June 23rd, 2004

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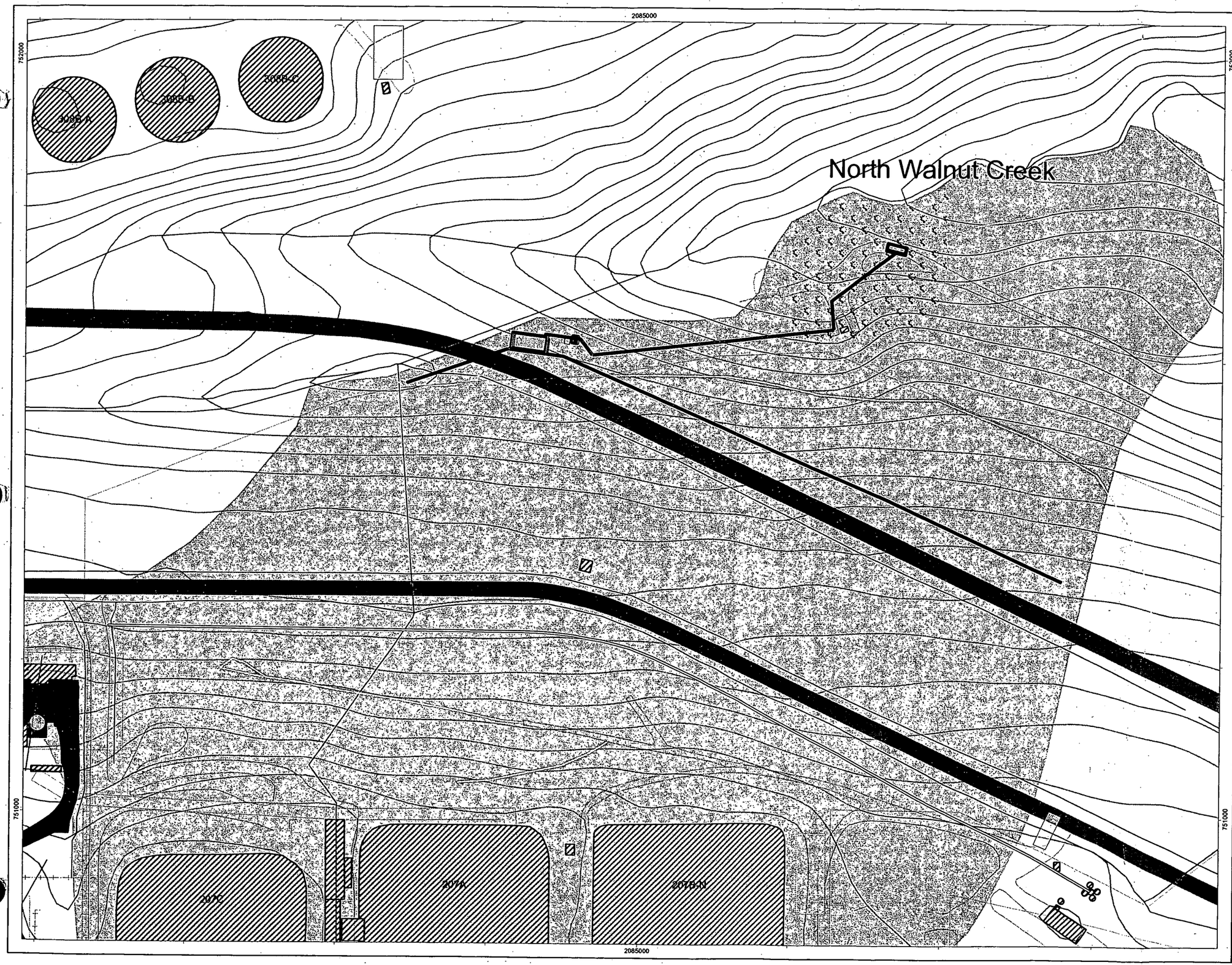
187



Rocky Flats Environmental Technology Site

Figure 7-3

Proposed Action at the Solar Evaporation Ponds Plume

- Proposed Phyto-remediation
- French Drain
- Treatment Gallery
- Collection Trench
- Transmission Pipe
- Contours
- Dirt Roads
- Trails
- Fence
- Streams
- Nitrate Plume
- Individual Hazardous Substance Site
- Potential Area of Concern
- No Further Action PACs in 1992
- Under Building Contamination
- Demolished Structure
- Standing Structure
- Paved Surface
- Lake

N W E S

1:1,466

1 inch equals 120 feet

0 25 50 100 150 200 Feet

State Plane Coordinate Projection
Colorado Central Zone (3476)
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

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Prepared For: KAISER•HILL COMPANY

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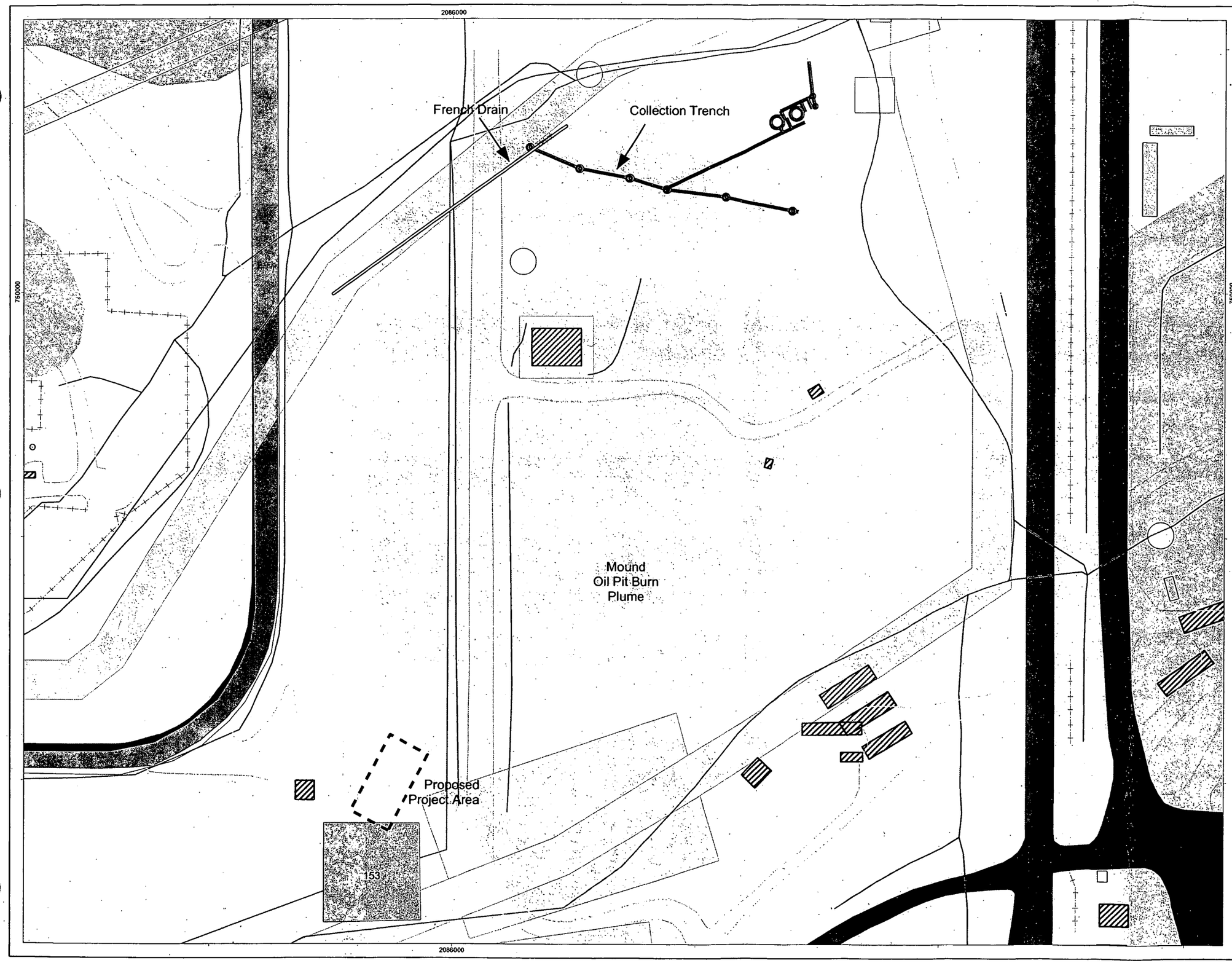

Rocky Flats Environmental Technology Site

Figure 7-4

Proposed Action at the Mound/Oil Burn Pit #2 Plume

- Break in Pipe
- French Drain
- Collection Trench
- Treatment Gallery
- Dirt Roads
- Trails
- Fence
- Streams
- Project Area
- Demolished Structure
- Standing Structure
- Paved Surface
- Lake
- IHSS 153
- Other IHSS
- UBCs
- PACS
- PACs NFA in 1992
- Composite VOC Plume
- Nitrate Plume

N W E S

1:913

1 inch equals 76 feet

0 15 30 60 90 120 Feet

State Plane Coordinate Projection
Colorado Central Zone (3476)
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared By: CH2MHILL

Prepared For: KAISER•HILL COMPANY

MAP ID: GIS Dept. (303) 966-7707 June 23rd, 2004

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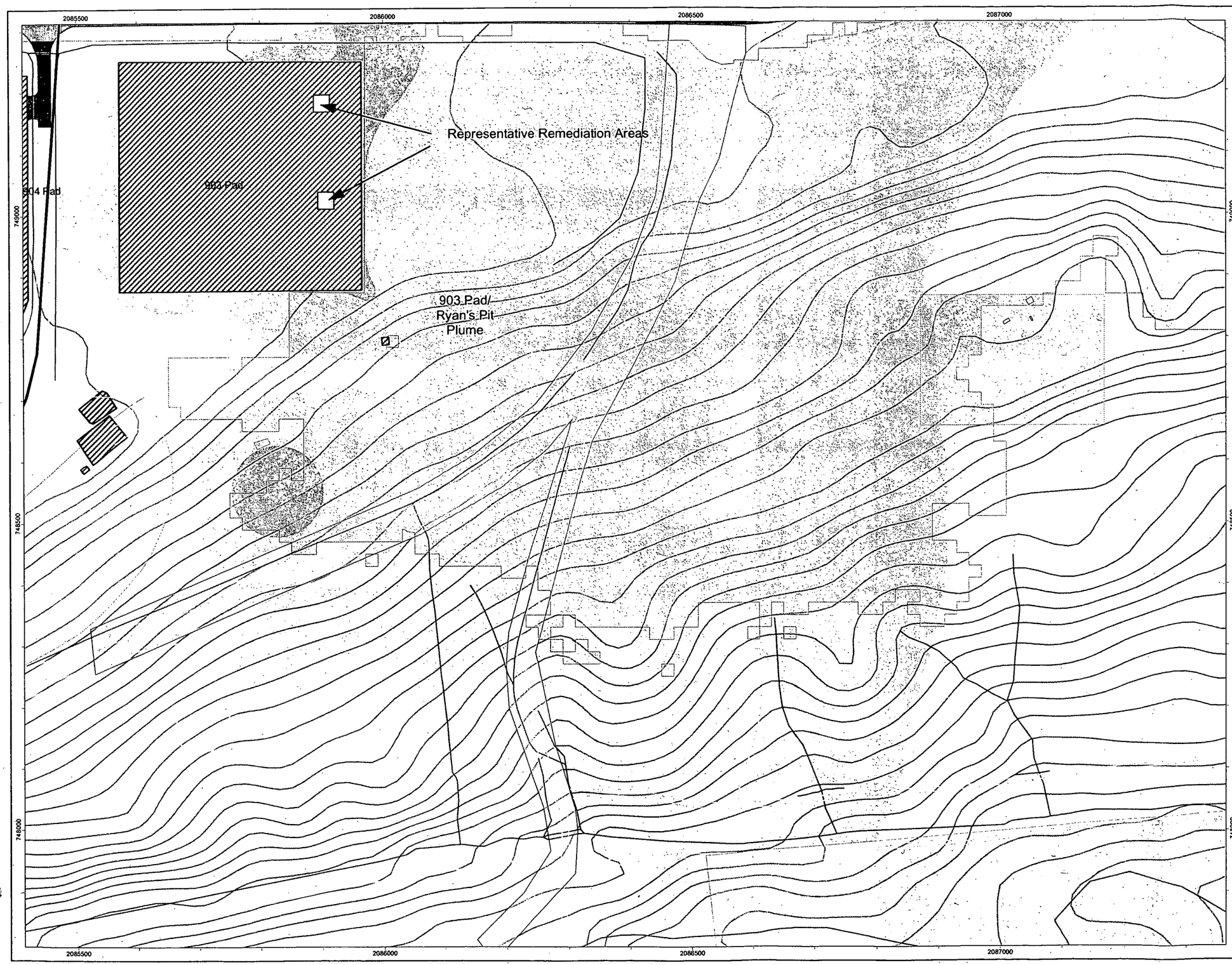

Rocky Flats Environmental Technology Site

Figure 7-5

Proposed Action at the 903 Pad/Ryan's Pit Plume

- Proposed Phyto Remediation
- Contours
- Dirt Roads
- Trails
- Fence
- Streams
- IA OU Boundary
- Demolished Structure
- Standing Structure
- Paved Surface
- Lake
- Individual Hazardous Substance Site
- Under Building Contamination
- Potential Area of Concern
- No Further Action PACs in 1992
- Composite VOC Plume
- Nitrate Plume

N W E S

1:1,808

1 inch equals 150 feet

0 30 60 120 180 240 Feet

State Plane Coordinate Projection
Colorado Central Zone (3476)
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared By: CH2MHILL

Prepared For: KAISER•HILL COMPANY

MAP ID: GIS Dept. (303) 966-7707 June 23rd, 2004

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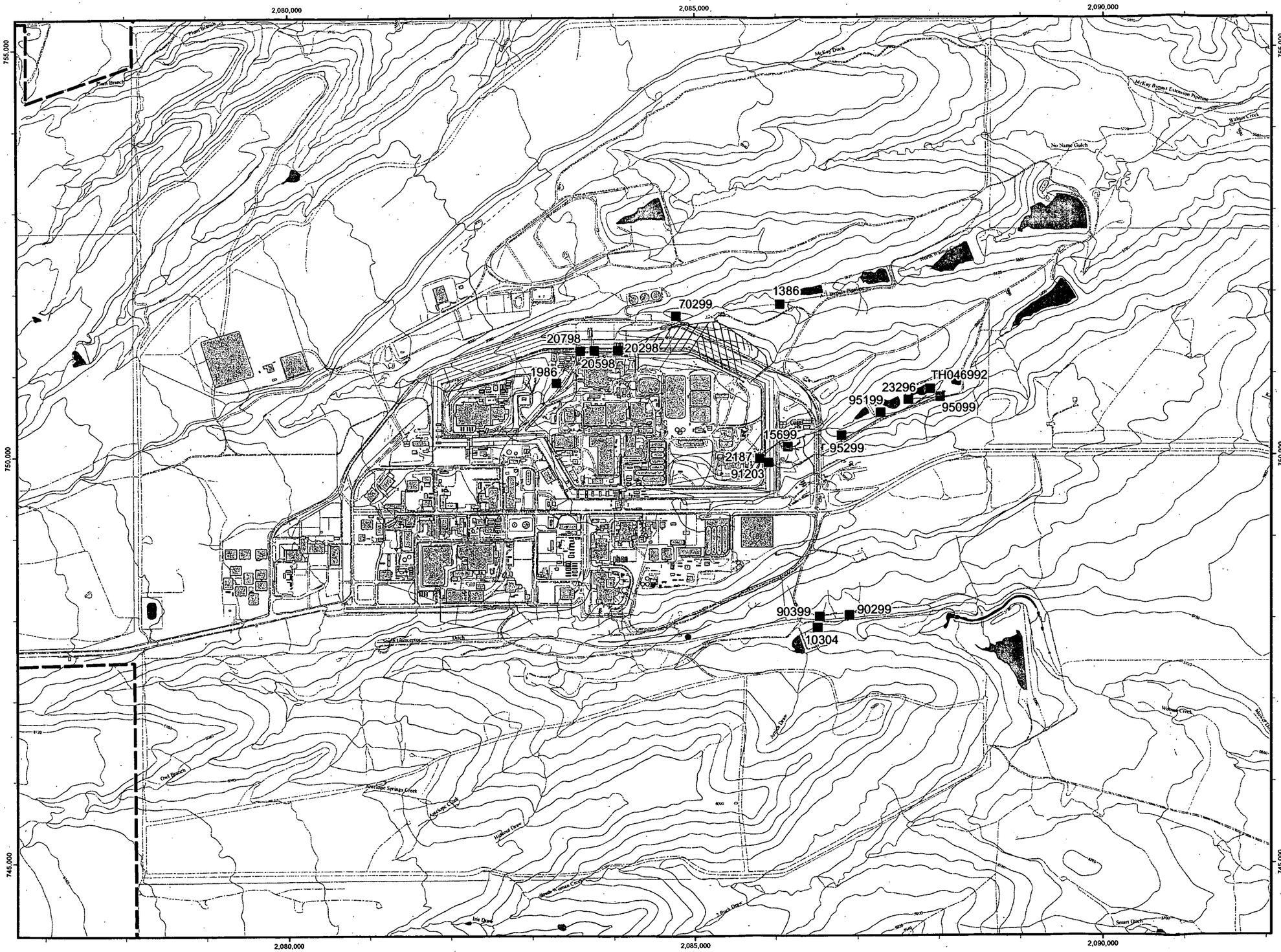

Figure 7-6
Proposed GW IM/IRA Performance Monitoring
November 9, 2004

Legend

- Proposed Performance Monitoring Well

Standard Map Features

- Building or structure
- Groundwater treatment system
- Lake or pond
- Stream, ditch, or other drainage feature
- Paved road
- Dirt road
- Trail
- Fence
- Topographic contour (20 foot)

DRAFT

Note:
These wells are a subset of the wells listed in the FY05 Integrated Monitoring Plan (IMP). See the IMP for analyte sampling frequency and analytes.

N

Scale = 1 : 14,400
1 inch represents 1,200 feet

600 0 600 1,200
Scale in Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: URS

Prepared for: KH RAMSEY-MILLER

November 30, 2004

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8.0 ENVIRONMENTAL IMPACTS (NEPA ANALYSIS)

8.1 Soils and Geology

In general, the remediation of a substantial amount of contaminated soil and/or weathered bedrock material will result in a long-term beneficial impact. Of the five areas to be remediated, only one, the Carbon Tetrachloride Plume (IHSS 118.1), which specifies excavation, will require a substantial amount of soil and/or weathered bedrock material to be removed. Two others, downgradient of the East Trenches Plume and downgradient of the SPP, which specify phytoremediation, will require a moderate amount of soil and/or weathered bedrock to be removed. The remaining two, Mound Site/Oil Burn Pit #2 and 903 Pad/Ryan's Pit Plumes, which specify in-situ enhanced biodegradation, will require minimal or no soil and/or weathered bedrock removal.

The proposed action for the Carbon Tetrachloride Plume has positive long-term impacts, because the majority of the CT source is anticipated to be removed, which greatly outweighs the potential short-term impacts discussed below. In the short term, remediation activities at the Carbon Tetrachloride Plume have removed approximately 15,000 cubic yards of soil and weathered bedrock in the immediate vicinity of Building 730, including 1,200 cubic yards of contaminated material. Soil with contaminant concentrations below WRW ALs will be stockpiled at the project site for later use as backfill. Removed soils above ALs would be placed in appropriate waste containers. Potentially adverse impacts include increased soil erosion and short term impacts to surface water quality caused by stockpiling the excavated material, though erosion controls are implemented to minimize this result.

Because of the large area of soil being removed, other surface soil contamination in the vicinity could potentially be mobilized during precipitation events and migrate into the open excavation, potentially contaminating groundwater with analytes not observed to date at this location. The depth of this excavation has left a good portion of the UHSU exposed in this area. Consequently, the accelerated action could potentially impact groundwater quality in the short term. This is the only location of the five that could have some impact on subsurface geology. The contaminated soil at IHSS 118.1 will be managed as waste and placed in appropriate containers for off-site shipment and disposal.

The areas downgradient of the East Trenches plume and downgradient of the SPP have phytoremediation identified as their remedy. Moderate soil disturbance will result from this activity because trees will have to be planted. The positive long-term impacts of this activity outweigh the potential short-term impacts to surface water and groundwater that could result from the planting of trees adjacent to the drainages. Soil excavated for tree planting is anticipated to contain contaminant concentrations below ALs and the excess will be spread in the planting area. The small volume of nonsoil waste generated will be disposed of as sanitary waste.

The Mound Site/Oil Burn Pit #2 and 903 Pad/Ryan's Pit areas have in-situ enhanced biodegradation specified as their remedy. There will be no soil and/or weathered bedrock

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disturbance generated by the remedial action at these two locations. The beneficial long-term impacts of this activity far outweigh the negligible short-term impacts to the subsurface. Potential short-term impacts include carrying potential surface and near-surface soil contamination into the subsurface via the borehole generated during insertion of the amendment.

8.2 Air Quality

Air quality environmental effects are determined by estimating potential increases in the concentrations of regulated pollutants in ambient air as a result of specified actions. The proposed groundwater remediation alternatives listed in this IM/IRA have very little potential to increase concentrations of regulated air pollutants. The source removal alternative and tree planting associated with phytoremediation have a potential to emit small quantities of fugitive particulate matter, and the source removal alternative has a potential to emit small quantities of noncriteria reportable pollutants and VOCs; however, they are not expected to exceed Colorado Air Quality Control Commission (CAQCC) Regulation Number 3 (Reg. 3) reporting thresholds and will be exempt from Air Pollutant Emission Notice (APEN) submittal requirements. Reg. 3 states that sources that are exempt from APEN reporting requirements are deemed to have a negligible impact on air quality.

The proposed groundwater remediation alternatives will result in minor, temporary air quality impacts only during active soil disturbance activities. There will be no future permanent sources of air pollutant emissions as a result of these alternatives. The proposed alternatives will not result in a significant impact to ambient air quality.

8.3 Water Quality

Remediation actions may, in the short-term, cause potential impacts to surface water quality, such as increased turbidity and contaminant transport resulting from erosion of disturbed soil. However, the remediation of groundwater contamination reduces the potential for long-term contaminant migration to surface water. Consequently, long-term impacts to surface water are projected to be beneficial. Long-term impacts to groundwater quality are also projected to be beneficial.

Erosion from the work areas will be controlled through prompt application of erosion control processes and materials. Prompt placement of erosion control matting and regular revegetation of excavated areas, and sloped areas in particular, will reduce the potential for adverse impacts to surface water quality.

In addition, there are potential short-term negative impacts associated with the use of amendments for in-situ enhance biodegradation, as proposed for the Carbon Tetrachloride Plume (IHSS 118.1), and Oil Burn Pit #2 Plume (IHSS 153), and potentially to be used at the 903 Pad (IHSS 112) and Ryan's Pit (IHSS 109) Plumes. As shown in the PU&D Yard Treatability Study, the reducing amendments have a surfactant effect and can cause a short-term increase in groundwater contaminant concentrations, and seasonal groundwater contaminant increases, when groundwater rises into contaminants and amendments that are unsaturated in the dry season (K-H, 2001c). The

reducing environment produced by the amendments can also cause release of arsenic, and potentially other metals, into the groundwater, although this release appears to be limited in areal extent to less than 10 feet from where the amendments have been introduced. However, the remediation of groundwater contamination reduces the potential for long-term contaminant migration to surface water. Therefore, the overall long-term impact to both groundwater quality and surface water quality is projected to be beneficial.

8.4 Human Health and Safety

Potential short-term human health impacts to the public and collocated workers from remediation activities include fugitive dust, exposure to radioactive materials (associated with exposure to soil with concentrations of radionculides below soil ALs), and traffic associated with on-site and off-site transportation of soil. Workers involved in remediation operations will also be subject to risks of operating heavy machinery.

As a measure of impacts to the public from remediation activities, the Cumulative Impacts Document (CID) (DOE 1997c) reports the following estimated annual radiological doses from RFETS closure air emissions: maximally exposed collocated worker, 5.4 mrem; maximally exposed member of the public 0.23 millirem (mrem); and population dose, 23 person-rem. The population dose will be expected to produce 0.012 latent cancer fatalities in the region of interest with a population of 2.7 million. Because these estimates include all RFETS closure activities, impacts from activities addressed in this proposed action will be a small fraction of those reported above.

Worker radiological dose estimates for all closure activities are presented in the CID (DOE 1997c), grouped by activity and building cluster. A total worker dose of 383 rem is reported for decommissioning and remediation activities for the 371, 707, 771, 776/777, 779, 881, 886, and 991 building clusters. An additional worker dose of approximately 12 rem is predicted for miscellaneous production zones, transuranic (TRU) cluster, and IA and BZ decommissioning and remediation activities. The total reported dose to workers for these closure activities is approximately 395 rem. Because doses from decommissioning will dominate these exposures, the proposed action is expected to be a small fraction of the 395 rem reported in the CID (DOE 1997c).

In practice, remediation activities, which address soil with potential radiological contamination, will be subject to the RFETS radiation protection program, which includes administrative controls limiting the dose to any involved worker to a maximum of 500 millirem per year (mrem/yr). Doses resulting from activities addressed in this IM/IRA are expected to comply with this limit. In addition, worker radiation protection for these activities will be governed by the As Low As Reasonably Achievable (ALARA) principle, which mandates that worker exposures be further minimized on a cost-effective basis, consistent with the activities being conducted.

In addition, chemical hazards would be mitigated by the use of PPE and administrative controls. Appropriate skin and respiratory PPE would be worn throughout the project. Routine VOC monitoring would be conducted with an organic vapor monitor for any employees who must work near the contaminated soil (i.e., soil sampling or excavation

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personnel). Based on employee exposure evaluations, the Site Health and Safety Officer may downgrade personal protective equipment requirements, if appropriate.

Risks to involved workers will be dominated by standard industrial hazards associated with heavy equipment operations associated with excavation, earthmoving, and transportation equipment. A project-specific HASP Addendum and JHA will be prepared before implementing the proposed action.

8.5 Ecological Resources

Impacts to the ecological resources were evaluated for the preferred alternative for each of the proposed actions. In general, many impacts associated with heavy equipment, noise, and human activity will be similar for each proposed action and are addressed together. Project-specific issues that impact threatened and endangered (T&E) species or wetlands are addressed for each specific project below.

Heavy equipment activities for the proposed actions will temporarily affect vegetation communities and wildlife habitat in and around each of the project areas. Temporary effects due to surface soil disturbance and noise associated with heavy equipment are expected. Physical alteration of the habitats could include degradation and/or temporary loss of existing habitat in the project areas. No permanent loss of habitat is expected from any of the proposed actions.

Throughout the duration of each project, sensitive wildlife species may avoid the areas. However, this is variable by species and for individuals. Some animals may habituate to the activity and not move far from the activities, while others may leave temporarily and return after project completion. Depending on the time of year that the activities occur, there may be some potential to impact migratory birds. Migratory birds are protected under the Migratory Bird Treaty Act. To meet the substantive requirements of the statute, the following actions will be implemented for the projects. Because no active nests are expected to be present in the project areas from September 15 through April 15, no nest surveys will be conducted during this time frame. However, from April 16 through September 14, nest surveys will be conducted every two weeks of vegetated areas in the project footprints. Any active nests located will be recorded by bird species. The nests will be removed and/or relocated, and the project will then be allowed to disturb the area.

Long-term impacts to ecological resources are not expected to be detrimental. Remediation activities should improve the habitat by reducing the potential groundwater contamination issues and revegetating areas with native plant species into areas that are currently dominated by mostly non-native species.

No impacts to the ecological resources beyond those mentioned above are expected at the IHSS 118.1 Carbon Tetrachloride Plume. The project area is outside current PMJM protection areas at RFETS, so no impacts are expected to the PMJM. No wetlands are present in the project area, and no impacts to migratory birds are expected.

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At the East Trenches Plume, phytoremediation is the preferred alternative. The locations proposed for the phytoremediation plantings are located within the PMJM habitat and potentially some wetland areas. Consultation with the USFWS for the PMJM impacts would likely be necessary to modify portions of the Programmatic Biological Assessment to allow this project within the construction footprint for the Pond Remediation and Removal activities. No additional adverse impacts to the PMJM would be expected beyond what would have already occurred through the pond remediation and dam notching activities. Potential temporary impacts would result from vehicles and human activity used to install the trees and irrigation systems and any potential maintenance of the irrigation system. The planting of trees would potentially enhance habitat for the PMJM along the pond edges and could be conducted as part of the revegetation activities that would take place after the remediation and dam notching were completed. Wetland impacts would be temporary and minimal, involving perhaps some vehicle traffic and planting of trees in or adjacent to wetland areas around the pond edges. The trees that survive in the long-term would potentially increase the diversity of the wetland areas and increase the amount of wooded wetland classifications at the Site, while providing additional nesting habitat for certain bird species that nest in the riparian woodland areas at the Site. Any potential impacts to migratory birds would be addressed as described above.

The SPP preferred alternative is also phytoremediation. Again, the locations proposed for the phytoremediation plantings are located within the PMJM habitat and potentially some wetland areas. Consultation with the USFWS for the PMJM impacts would likely be necessary to modify portions of the Programmatic Biological Assessment to allow this project to be conducted under the Miscellaneous Category of impacts. Potential temporary impacts would result from vehicles and human activity used to install the trees and irrigation systems and any potential maintenance of the irrigation system. The planting of trees would potentially enhance habitat for the PMJM along the stream. Wetland impacts would be temporary and minimal, involving perhaps some vehicle traffic and planting of trees in or adjacent to wetland areas along the stream. The trees that survive in the long-term would potentially increase the diversity of the wetland areas and increase the amount of wooded wetland classifications at the Site while providing additional nesting habitat for certain bird species that nest in the riparian woodland areas at the Site. Any potential impacts to migratory birds would be addressed as described above.

The proposed actions for both the Mound Site/Oil Burn Pit #2 Plume and the 903 Pad/Ryan's Pit Plume are *in-situ* enhanced biodegradation. The locations for the proposed actions for both projects are not located in PMJM habitat or in a wetland area. Besides the issues discussed at the beginning of this section, there are no other substantial ecological impacts from these projects. Any potential impacts to migratory birds would be addressed as described above.

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8.6 Cultural and Historic Resources

The Rocky Flats Plant site was placed on the National Register of Historic Places as a Historic District (5JF1227) on May 19, 1997. Historic District designation mandates compliance with the Historic Preservation Act of 1966, and the Programmatic Agreement among DOE, the Colorado State Historic Preservation Officer, and the Advisory Council on Historic Preservation Regarding Historic Properties at RFETS. While the proposed action will be conducted within the Historic District boundaries, no impact will occur to protected structures.

8.7 Visual Resources

Remediation activities will result in temporary and minor visual impacts during RFETS closure. However, the long-term visual changes to topography and vegetation cover resulting from remediation activities will not be noticeable. Remediation activities include the revegetation of soil to a native grassland appearance. Revegetation areas will be permanently revegetated using the appropriate native plant species mixture. Impacts to visual resources will be temporary and insignificant.

8.8 Noise

Remediation activities include a temporary increase in local noise levels from the operation of heavy equipment, and the loading and hauling of wastes for off-site disposal. The CID (DOE, 1997b) found that noise levels from industrial activities within the RFETS boundary were not distinguishable from background traffic noise levels. Noise levels from the proposed action are not expected to be perceptible at offsite locations, and impacts from increased noise will be insignificant.

The primary source of noise to nearby residential areas is traffic movement along local streets and state routes. Remediation activities will result in higher public noise levels due to the increased number of trips for waste transport. However, the effects will be short-term, occurring intermittently during daylight hours, and will be minimal lasting for only a few months. The CID Update (DOE, 2001b) identified increased offsite traffic relative to the CID (DOE, 1997b) due to the shorter closure time, but found that the additional traffic noise will not cause a doubling of noise levels. It indicated that most public reviews of traffic noise by federal and state agencies consider a doubling of sound (10 decibels or greater) to be a moderate to substantial increase. Because traffic, including truck traffic, is already prevalent along the proposed trucking routes, it was concluded in the CID Update (DOE, 2001b) that the potential impact is considered low. Given that the CID (DOE, 1997b) and CID Update (DOE, 2001b) analyses considered off-site waste management transport (low-level, low-level mixed, and sanitary waste) and work force commuters, in addition to remediation waste transport, offsite noise impacts from remediation activities alone will be considerably less.

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8.9 Transportation

The proposed remediation activities will produce soil and sanitary wastes that require on-site transportation for interim storage, and off-site transportation for disposal at off-site facilities. Potential transportation impacts include increased air emissions, increased traffic congestion, and transportation accidents. Tailpipe emissions and airborne particulate matter generated by the anticipated truck traffic is projected to be well below regulatory standards and will not reach a level of concern. Because of stringent U.S. Department of Transportation (DOT) packaging and shipping standards, cargo-related accidents will pose minimal concern to human health and safety. The CID Update (DOE, 2001b) analyzed traffic in terms of highway and road congestion resulting from RFETS-related traffic. The effects were not projected to be substantial.

In addition to being analyzed in the CID (DOE, 1997b) and CID Update (DOE, 2001b), transportation of RFETS wastes has been analyzed from a National Environmental Policy Act (NEPA) perspective in the following NEPA documents: Final Waste Management Programmatic Environmental Impact Statement for Managing, Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DOE, 1997c); Environmental Assessment Finding of No Significant Impact for Temporary Storage of Transuranic and Transuranic Mixed Waste (DOE, 1999c); and Attachment 3 of the RSOP for Facility Disposition (DOE, 2004b). These documents analyzed impacts of offsite shipment of RFETS waste to potential treatment and disposal locations including the Nevada Test Site (NTS), Envirocare, and Hanford. The RSOP for Facility Disposition, in particular, addressed remediation waste (DOE, 2004b). These studies have found that impacts of waste shipments are small, and the shipments themselves contribute to an overall reduction of risk at RFETS.

8.10 Cumulative Effects

The activities proposed in this IM/IRA support the overall mission to clean up RFETS and make it safe for future uses. The cumulative effects of this broader, sitewide effort are presented in the CID (DOE, 1997b) and CID Update (DOE, 2001b), which describe the short- and long-term effects from the overall cleanup mission.

The primary focus of the CID (DOE, 1997b) was on cumulative impacts resulting from on-site activities implemented through RFETS closure. Cumulative impacts result from the proposed RFETS activities and the effects of other actions taken during the same time in the same geographic area, including off-site activities, regardless of what agency or person undertakes such other action. The CID Update (DOE, 2001b) analysis included updated on-site and off-site transportation requirements, as well as several new off-site activities, although the future non-DOE projects are relatively uncertain. Increased traffic congestion will be the most noticeable impact according to the CID Update (DOE, 2001b). Air pollutants and noise will also have adverse impacts; however, the impacts are expected to be short-term in nature, with staggered project start and completion dates. Most people will perceive a positive, long-term visual and "quality of life" benefit, as RFETS infrastructure and remediation equipment is removed, returning RFETS to a more natural appearance.

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The cumulative impacts of the proposed actions are expected to be similar to those analyzed in the CID (DOE, 1997b) and 2000 CID Update Report (DOE, 2001b). Over the short term, personnel staffing will have a neutral effect on the existing workload for Site operations, and there will be increased air emissions, ecological impacts, visual impacts, noise, and traffic impacts resulting from remediation activities. These short-term impacts will be minimal and temporary. Long-term impacts facilitate future use of the Site and fulfill the mandated cleanup objectives.

8.11 Unavoidable Adverse Impacts

The activities proposed in this IM/IRA are not expected to result in any adverse environmental impacts. All environmental impacts are expected to be minimal and/or temporary. Some permanent loss of wetlands and endangered species habitat may result from the remediation activities; however, such losses are a minor fraction of the total resources present at RFETS.

8.12 Irreversible and Irretrievable Commitments of Resources

The proposed actions will result in a variety of permanent commitments of resources; however, they are not expected to result in a substantial loss of valuable resources. Most of the resources used for the work are permanently committed to implementation of the accelerated action. Irreversible and irretrievable resources are defined as resources that are either consumed, committed, or lost. For the proposed actions, irreversible and irretrievable resources include the following:

1. Consumptive use of geological resources (e.g., backfill for soil excavation) may be required for remediation activities involving excavation. Supplies of these materials will be provided by an on-site or off-site commercial borrow source. However, adequate supplies are available without affecting local demand for these products.

2. Fuel consumed by construction equipment and vehicles used for the proposed actions will not be recovered.

3. Isolated wetland areas may be impacted (temporarily) by the proposed actions. Long-term direct impacts to the floodplain resulting in changes of flood elevations will not occur.

4. A long-term commitment of personnel and funds may be required to perform post-closure inspection, maintenance, and monitoring activities.

5. Incidental resources that are consumed, committed, or lost on a temporary and/or partial basis during remediation include operational personnel and equipment, *in situ* bioremediation additives, and some construction materials.

Monitoring and maintenance activities will be performed, as necessary, to ensure long-term protection of human health and the environment.

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9.0 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

The Groundwater IM/IRA is an interim action to address groundwater that is contaminated by the AOIs identified in Section 3.0. The action involves several different treatment technologies to be implemented at four different locations and the possible implementation of treatment at one other location after further evaluation of technologies. Table 7-1, presents the technologies/locations, which are referred to as specific "projects" in this ARARs section. The proposed accelerated action will attain identified ARARs of environmental laws to the extent practicable.

The identified ARARs for the IM/IRA are listed in Appendix I and the consideration of key environmental laws resulting in ARAR identification are briefly discussed in this section. In the Appendix I, each ARAR is identified as pertaining to the chemical contaminant (AOI) being addressed in this IM/IRA, the location of the project, and/or action-specific aspects of the project and treatment technology installation and operation, as indicated by a C, L and/or an A, respectively. The discussion in this section and the Appendix I table Comment column provides information regarding the chemical contaminant, location, and/or action-specific aspects of ARARs pertaining to particular projects.

This IM/IRA recognizes the continued overall contaminated groundwater monitoring and management control regime in place at RFETS, but this monitoring and management control is not part of the IM/IRA, and therefore the identified ARARs only pertain to the monitoring and management controls for the particular projects. Requirements with long-term stewardship implications are summarized in Section 7.8.

Under CERCLA, the administrative requirement to apply for and obtain environmental permits for actions performed on Site is waived. RFCA paragraphs 16 and 17 provide the conditions for the CERCLA permit waiver for cleanup actions at RFETS. For proposed actions that qualify for the permit waiver, the following information is required:

a) Identification of each permit that would be required;

b) Identification of the standards, requirements, criteria, or limitations, that have to be met in order to obtain, each permit; and

c) Explanation of how the response action proposed will meet the standards, requirements, criteria, or limitations identified in subparagraph b (immediately above).

Permit requirements and waiver information that may pertain to the IM/IRA projects are discussed below.

9.1 Groundwater Quality

The Federal Water Pollution Control Act (also known as the Clean Water Act [CWA], 33 U.S. Code [USC] 1251, *et seq.*) establishes criteria for states to adopt water quality

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standards and implementation requirements. Colorado has promulgated water quality standards pursuant to the CWA criteria through state regulations.

The groundwater quality standards adopted by Colorado for the RFETS "specified area" groundwater classification are identified in Colorado Water Quality Control (CWQC) Regulation No. 42, *Site Specific Water Quality Classifications and Standards for Groundwater* (CWQC Reg. 42), at CWQC Reg. 42.7(1)(c). CWQC groundwater standards are chemical-specific ARARs. The "specified area" is defined as all unconfined groundwaters within the USHU[2,3], the Arapahoe and Upper Laramie aquifers not hydraulically connected to the UHSU, and the Laramie-Fox Hills aquifer within the area specified in CWQC Reg. 42 Figure 1 (which coincides with the RFETS fence line). As discussed in Section 2.5, the Upper Laramie and Laramie-Fox Hill aquifers are not impacted by the UHSU (Hurr, 1976; RMRS, 1996).

Pursuant to CWQC Reg. 42.7(1)(b), the Site-specific groundwater classification for the RFETS "specified area" is surface water protection. The groundwater quality standards for the AOIs addressed in this IM/IRA are the associated statewide or site-specific surface water quality standards promulgated by the Colorado Water Quality Control Commission (WQCC). RFCA Attachment 5, Action Levels and Standards for Surface Water, Groundwater and Soils, Table 1, Surface Water Action Levels and Standards, is consistent with the WQCC promulgated surface water quality standards.

The location pertinent to measurement for compliance with the groundwater quality ARAR is the AOC boundary wells. The location of the AOC boundary wells are based on consideration of regulatory provisions concerning groundwater POCs as defined by CWQC Reg. 41.3 (10). The POC is a vertical surface that is located at some specific distance hydrologically downgradient of the activity being monitored for compliance. Generally, the groundwater POC is where a facility should monitor groundwater quality and/or achieve specified cleanup levels to achieve facility-specific goals (EPA, 2002). The agencies responsible for implementation of CERCLA, RCRA, and/or CHWA have some flexibility in establishing the groundwater POC. Pursuant to CWQC Reg. 41.5.C.5, the implementing agencies (in the case of RFETS, CDPHE's Hazardous Materials/Waste Management Division and EPA) may select a groundwater POC that is more or less stringent than would be achieved under the promulgated statewide or site-specific standards.

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[2] Pursuant to CWQC Reg. 42.5 (7), the UHSU is the uppermost layer of groundwater incorporating any aquifer or other zone of groundwater occurrence which is first encountered beneath the ground surface and includes all saturated geologic formations, unconsolidated alluvium and colluvium, and hydraulically connected zones in bedrock. See Reg. 42 1996 Revisions Statement of Basis and Purpose discussion regarding use of the UHSU as the "specified area" to protect quality in groundwater that does not meet the useable quantity expectations associated with the use of the term "aquifer".

[3] Pursuant to Colorado Water Quality Control Regulation 42.7(1)(a) the UHSU includes the unconsolidated Quaternary and Rocky Flats alluvium, colluvium and valley fill alluvium, and weathered claystone and hydraulically connected sandstone bedrock of the Arapahoe and Upper Laramie formations.

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The CWQC Reg. 42 site-specific standards do not identify any RFETS-specific groundwater POCs.[4] The CWQC Reg. 41 statewide standards (for radionuclides) do include criteria for establishing the POC as specified in Reg. 41.6.C. The main criterion affecting the POC is whether the contamination is identified and reported to the CERCLA, RCRA/CHWA implementing agency prior to September 30, 1992. Because groundwater contamination was identified and reported prior to that date, the regulations specify that the POC is the site boundary or, if closest to the contamination source, the hydrologically downgradient limit of the area in which contamination exists when identified. The groundwater POCs for this IM/IRA are identified as AOC boundary wells and are shown on Figure 5-1.

Groundwater at RFETS is not a source of drinking water, so there is no identified drinking water quality ARARs. However, the WQCC promulgated surface water quality standards are adequately protective for drinking water use.

9.2 Surface Water Quality

The projects are being implemented because contaminated groundwater does or may reach and contaminate surface water. As discussed in the chemical-specific groundwater quality ARAR, the promulgated surface water and groundwater quality standards are the same. Statewide and RFETS-specific standards are promulgated in CWQC Regs. 31 and 38, respectively.

Surface water quality is measured at surface water POCs; however, the CWQC regulations do not establish surface water POCs for RFETS. RFCA Attachment 5, section 2 establishes surface water POCs during active remediation at the outfall of the A, B and C terminal ponds and at the eastern RFETS boundary (intersection of Walnut and Woman Creeks with Indiana Street).

Although it is anticipated that project performance monitoring may be implemented at locations in surface water upstream of the surface water POCs, the location-specific ARAR is the current Attachment 5 surface water POCs.

The discharge of pollutants from certain point sources into surface waters of the United States requires a permit under the National Pollutant Discharge Elimination System (NPDES), 33 USC 1342, 40 CFR 122S. None of the projects will constitute a point source discharge subject to NPDES point source discharge permit requirements.

No dredging or filling will occur for these projects, so there will be no discharge of this type of material into waters of the United States.

[4] See Reg. 42 February 4, 1991 Statement of Basis and Purpose discussion regarding not establishing a POC at that time, and essentially deferring to the agency or agencies that may have regulatory authority to implement the classifications and standards in the future. Thus, the POCs established in this Technical Memorandum do not depend on any POC-related rulemaking proceedings by the WQCC.

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9.3 Storm Water

No significant surface water impacts are anticipated as a result of storm water events. However, projects that will disturb more than 1 acre and are located outside the IA, which has an effective NPDES Permit for Storm Water, would require an NPDES Storm Water Permit for Construction Activities. Because the total area of the East Trenches and possibly the Ryan's Pit Plume projects trigger the NPDES storm water permit requirement, the following information is pertinent to the CERCLA permit waiver.

9.3.1 Permit Required

Because the East Trenches project is greater than one acre in size and lies outside of the Site IA, an NPDES General Storm Water Permit for Construction Activities would be required. The permit is found at 40 CFR Part 122, and is obtained by filing a Notification of Intent (NOI) with EPA. This IM/IRA serves as the NOI for the East Trenches Project.

9.3.1.1 Requirements to Obtain a Permit

Because the storm water permit for construction activities is a general permit, it has been through public comment and promulgated by EPA. Obtaining the permit is through the NOI (i.e., a letter submittal to the agency containing basic information about the project). The permit requires the installation of best management practices (BMPs) and structural storm water controls, such as silt fences, to protect downstream waters from potential surface water contaminants (for example, sediment-laden runoff). These requirements will be part of the project plan.

9.3.1.2 How Storm Water Control Measures Meet the Requirements

The total area of disturbed soil is approximately one to three acres for each planting project, including the area of miscellaneous construction activities (e.g., vehicle traffic). Surface water control measures will be used to minimize surface water contact with potentially contaminated soil or groundwater and minimize erosion effects during the construction activities. Precipitation falling on areas where construction is in progress will be diverted to existing surface water drainage ditches. Other shallow ditches will be temporarily constructed as needed to prevent sediment-laden stormwater from flowing directly into the B-Series ponds. Disturbed soil surfaces will be stabilized using revegetation hydromulch, straw-mulch, silt fencing, rip-rap and other storm water BMPs to minimize soil erosion, sediment transport, and surface water quality degradation until the required vegetation is established. The use of straw-mulch, adequately spaced silt fences, and other appropriate measures minimize soil loss while vegetation becomes established.

9.4 Remediation Wastewater

Remediation wastewater generated during construction activities is not expected; however, if produced, it will be managed consistent with provisions of the RFCA Implementation Guidance Document (IGD) (DOE et al., 1999). Remediation wastewater, if produced, will be collected, characterized, and transferred to the Central Water Treatment Facility, which is operated pursuant to RFCA, or appropriate off-site

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treatment facility or it will be directly discharged in accordance with requirements of the Site's Incidental Waters Program (K-H, 2003d).

9.5 Air Quality

All proposed projects have very little potential for hazardous air pollutant, including radionuclide, emissions. The proposed source removal at IHSS 118.1, and tree planting for phytoremediation at the East Trenches and SPP areas have the potential to generate fugitive particulate emissions. No potential radionuclide emissions from the treatment technologies have been identified. However, normal perimeter compliance air monitoring pursuant to Subpart H of 40 CFR Part 61 for activities within DOE facilities that have the potential to emit radionuclides other than radon will be conducted during the source removal and tree planting.

Colorado Regulation No. 1 (5 CCR 1001-3) governs opacity and particulate emissions. Section II of Regulation No. 1 addresses opacity and prohibits stack emissions from fuel-fired equipment exceeding 20 percent opacity. Section III addresses the control of particulate emissions. Fugitive particulate emissions will be generated from source removal, tree planting, and transportation activities. During excavation and backfilling activities, dust minimization techniques, such as water sprays, will be used to minimize suspension of particulates. In addition, dust generating activities will not be conducted during periods of high wind. The substantive requirements of Regulation No. 1 will be incorporated into a Dust Control Plan, which will define the level of particulate control for the projects.

Colorado Regulation No. 3 (5 CCR 1001-5) provides CDPHE with the authority to inventory emissions and Part A describes APEN requirements. Air quality management SMEs will evaluate the project emissions and, if applicable, an APEN will be prepared to facilitate CDPHE's inventory process.

The final surface of the backfilled excavations will appropriately reduce the potential post-action wind erosion of soil and subsequent particulate emissions.

9.6 Endangered Species

The SPP and East Trenches Plume projects will be implemented in locations close to the areas of suitable habitat for the PMJM, a listed threatened species under the Endangered Species Act (ESA), 16 USC 1531, *et seq*. Consultation with the USFWS will be required for any location and action that potentially conflicts with the purposes of the ESA to protect the listed species.

9.7 Wetlands

The projects are not anticipated to impact any wetlands; however, a determination of potential wetland impacts and possible mitigation requirements will be conducted for the East Trenches and SPP project locations.

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9.8 Migratory Birds

Construction activities may impact migratory birds protected by the Migratory Bird Treaty Act, and the Fish and Wildlife Conservation Act. Due to the variations in potential impacts depending upon the season and nesting schedules for migratory birds, the substantive requirements of these federal statutes will be evaluated by the Site Ecology group prior to conducting activities associated with the proposed action. The substantive requirements identified during the evaluation will be implemented throughout the construction process.

10.0 ADMIMINISTRATIVE RECORD REQUIREMENTS

This section identifies the documents that constitute the AR file for the Groundwater IM/IRA. Upon completion of the public comment period, comments received from the public will be added to the AR file, along with the Responsiveness Summary and the LRA approval letter. LRA approval of this Groundwater IM/IRA and associated major and minor modifications constitutes approval of the AR file.

AR file documents for the Groundwater IM/IRA are listed below:

- DOE, 1997d. OU1 Corrective Action Decision/Record of Decision, Rocky Flats Environmental Technology Site, Golden, Colorado, August.
- DOE, 1998. Minor Modification to the Modified Proposed Action Memorandum for the Passive Seep Interception and Treatment System, Operable Unit 7, Rocky Flats Environmental Technology Site, Golden, Colorado, June.
- DOE 1999. Final Mound Site Plume Project Closure Report, Fiscal Year 1998 RF/RMRS-98-289.UN, May.
- DOE 2000a. Final East Trenches Plume Project Closeout Report, Fiscal Year 1999 RF/RMRS-99-443.UN, February.
- DOE 2000b. Solar Ponds Plume Project Construction Closeout Report, Fiscal Year 1999, RF/RMRS-99-444.UN, Rev. 1 (not approved).
- DOE, 2001a. Final Major Modification to the Operable Unit 1 Corrective Action Decision/Record of Decision, Rocky Flats Environmental Technology Site, Golden, Colorado, January.
- DOE, 2003a. ER RSOP FY03 Notification #03-14 for IHSS Group 000-2, October.
- DOE, 2003b. Annual Report For The Rocky Flats Environmental Technology Site Groundwater Plume Treatment Systems, January through December 2002, Golden, Colorado, May.
- DOE (in progress). Interim Measure/Interim Remedial Action (IM/IRA) Decision Document and Closure Plan for the Present Landfill at the Rocky Flats Environmental Technology Site, Golden, Colorado.
- EG&G 1995a. Geologic Characterization Report for the Rocky Flats Environmental Technology Site, Golden, Colorado.
- EG&G 1995b. Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site, Golden, Colorado.

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- K-H, 2001c. Final PU&D Yard Plume Enhanced Natural Attenuation Treatability Study Report, September.
- K-H, 2004c. Evaluation of Natural Attenuation and Biodegradation Potential of Chlorinated Aliphatic Hydrocarbon Compounds in Groundwater at Rocky Flats, Rocky Flats Environmental Technology Site, Golden, Colorado, 04-RF-00358, March.
- K-H, 2004d. Preliminary Draft. Groundwater and Soil Remedial Action Objectives Technical Memorandum.

The following information repositories have been established to provide public access to the Groundwater IM/IRA Project AR:

U.S. Environmental Protection Agency (EPA)
Region VIII
Superfund Records Center
999 18th Street, Suite 500
Denver, Colorado 80202-2466
(303) 293-1807

U.S. Department of Energy Rocky Flats Public Reading Room
Front Range Community College Library
3645 West 112th Avenue, Level B
Westminster, Colorado 80030
(303) 469-4435

Colorado Department of Public Health and Environment (CDPHE)
Information Center, Building A
4300 Cherry Creek Drive South
Denver, Colorado 80220-1530
(303) 692-3312

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11.0 RESPONSIVENESS SUMMARY

Responses to comments received during the formal comment period, including comments from the regulatory agencies, will be documented and included as an appendix once comments are received.

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12.0 REFERENCES

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Groundwater IM/IRA
Appendix A

Groundwater Sample Data – For VOCs Not Selected as AOIs

(Figures presented on CD-ROM at back of document)

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Groundwater IM/IRA
Appendix B

Uranium – Inductively Couple Plasma/Mass Spectrometry Results

Appendix B – Uranium - Inductively Coupled Plasma/Mass Spectrometry Results

To determine the presence of anthropogenic versus natural uranium in groundwater, a sampling and analysis plan was developed by the Colorado Department of Public Health and Environment (CDPHE), in coordination with Site personnel, to analyze samples using High Resolution Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) (Pottorff, 2004). Groundwater samples were collected in 1999, 2000, and 2002, and analyzed at Los Alamos National Laboratory (LANL) (Murrell and Brink, 2000a; 2000b; 2001; 2002a; 2002b).

Figure B-1 is a map of the Rocky Flats Environmental Technology Site (RFETS) with the High Resolution ICP/MS sample results, including a symbol for each sample location indicating a "definitive" (anthropogenic), "suggestive" (anthropogenic), or "natural" uranium signature. A three-isotope plot of the ICP/MS data is displayed on Figure B-2. A description of the plot, and interpretation of the data, is provided with the figure. For each sample result, LANL personnel determined whether the uranium isotopic signature was "definitive anthropogenic," "suggestive anthropogenic," or "nonanthropogenic" [i.e., natural uranium].

On Figure B-2, sampling locations with a "definitive anthropogenic" signature are labeled with the well number from where the sample was collected. Some wells were sampled multiple times. The majority of data points on Figure B-2 are clustered near the intersection of the natural ratios, indicating the uranium is from a natural source.

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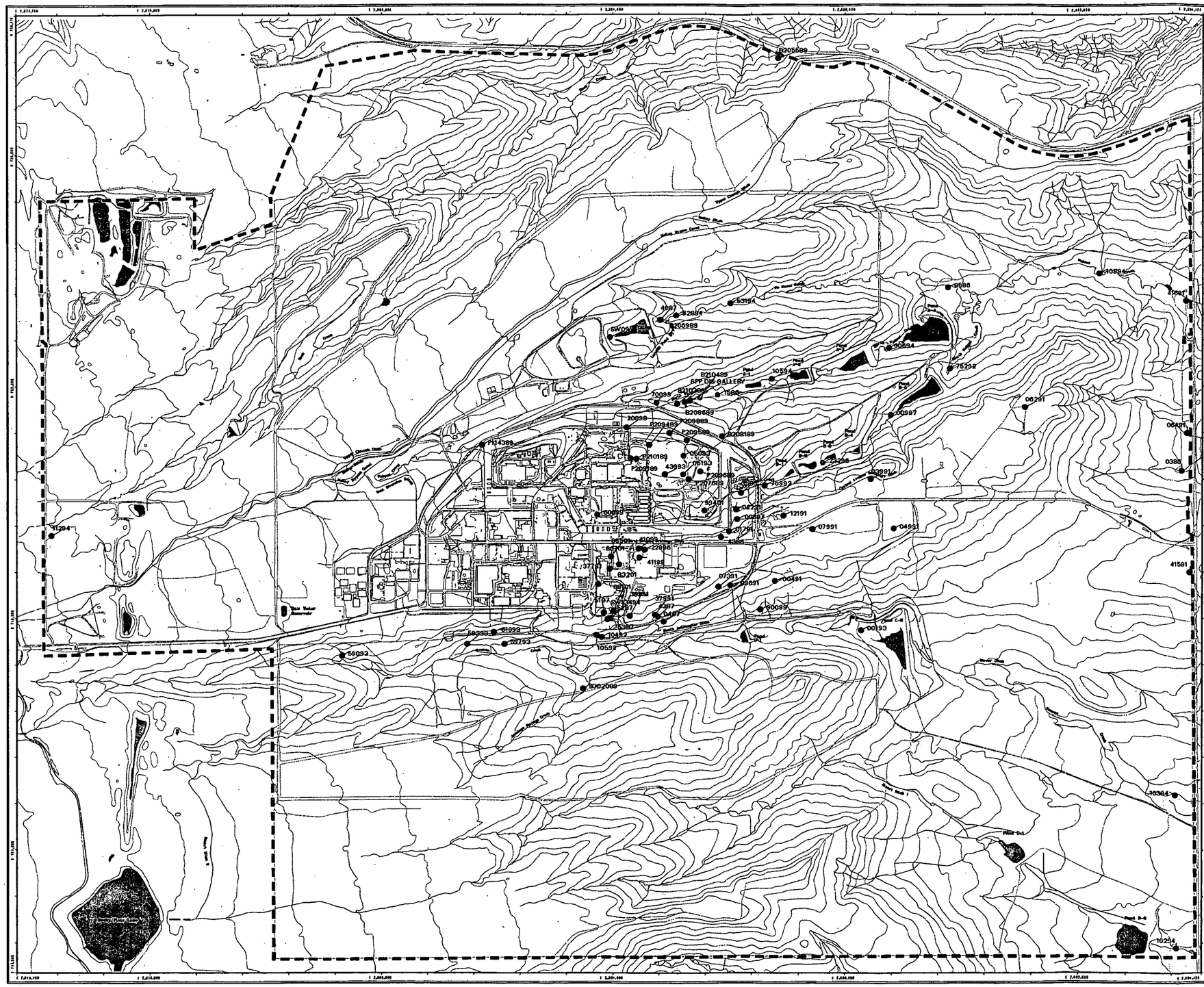

Rocky Flats Environmental Technology Site

Figure B-1

Groundwater Analysis
LANL High Resolution ICP/MS

EXPLANATION

- Natural Uranium Signature (with Sample Location)
- Suggestive Anthropogenic Signature (with Sample Location)
- Definitive Anthropogenic Signature (with Sample Location)

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Topographic Contour (20-Foot)
- Rocky Flats Environmental Technology Site boundary
- Roads

DATA SOURCE BASE FEATURES:
Buildings, towers, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G R&S, Las Vegas. Digitized from the orthophotographs. 1/25

Topographic contours were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

NOTES:

Detection of an anthropogenic uranium signature only indicates the nature of the uranium source material. It does not indicate the concentration of uranium observed in the groundwater. The "Natural", "Suggestive", and "Definitive" symbols are based on the interpretation of LANL personnel, with the following modifications:

- Location 05193 assigned a "definitive" symbol, instead of "natural" label originally assigned, because isotopic ratios indicated "definitive."
- Location SW097 assigned a "definitive" symbol, instead of a "suggestive signature", because isotopic ratios similar to other "definitive" wells.
- Location B208189 assigned a "natural" symbol, instead of definitive" symbol, because the ratios (U236/U238: -8.43E-7, and U235/U238: 0.007271) indicated "natural."
- Locations 05287 and 01586 assigned a "suggestive" symbol, instead of "natural", based on TIMS analysis results.

Note: If more than one sample was analyzed for one location, with different results (i.e., different signature types), then the more stringent of the signature types was applied to this map.

Scale = 1 : 21330
1 inch represents approximately 1778 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: CH2MHILL

Prepared for: KAISER-HILL COMPANY

December 09, 2004

NT_Svr w:/projects/fy2003/03-0388/murrell_analysis_fig-b1.aml

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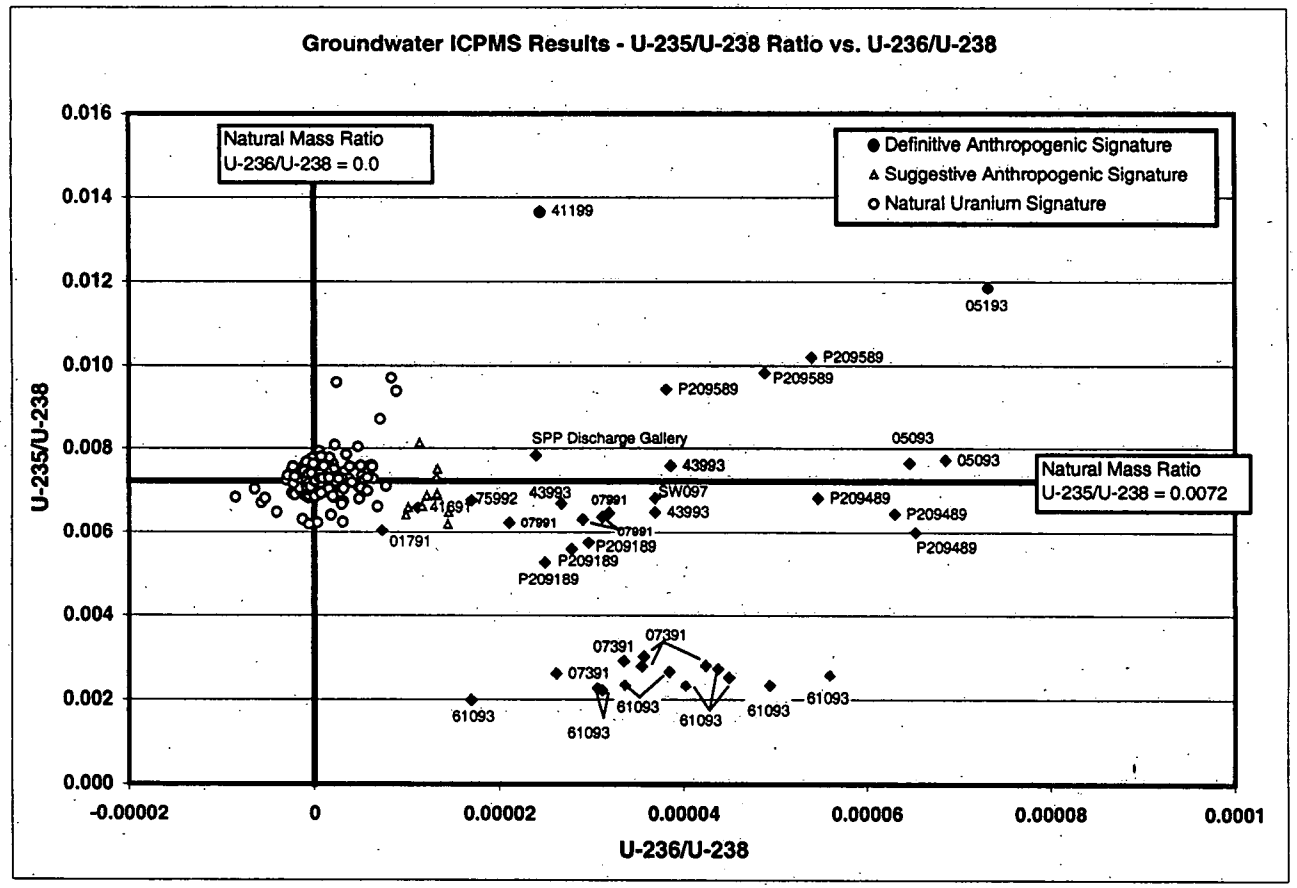
Figure B-2. Groundwater ICP/MS Analysis – Uranium Three-Isotope Plot



The bold horizontal line indicates the natural uranium ratio of U-235/U-238. A greater distance above the line indicates a higher proportion of U-235 (i.e., enriched uranium signature). A greater distance below the line indicates a higher proportion of U-238 (i.e., depleted uranium signature). The bold vertical line indicates the natural uranium ratio of U-236/U-238. Because natural uranium has no U-236, points farther from the vertical represent a more definitive man-made signature. The intersection of the vertical and horizontal lines, with the large cluster of data points, is representative of natural uranium.

Notes: The "Definitive Anthropogenic Signature", "Suggestive Anthropogenic Signature", and "Natural Uranium Signature" symbols are based on the interpretation of LANL personnel, with the following modifications: 1) Location 05193 (upper right of plot) was assigned a "definitive" symbol, instead of the "natural" label originally assigned, because the ratios indicated "definitive", 2) Location SW097 (in the center of plot) was assigned a "definitive" symbol, instead of a "suggestive signature", because the ratios were similar to other "definitive signature" locations; and 3) Location B208189 (in cluster of "natural" data points) was assigned a "natural" symbol, instead of a "definitive" symbol, because the ratios (U236/U238 ratio: -8.43E-7, and U235/U238 ratio: 0.007271) placed it at the intersection of the natural ratios.

Groundwater IM/IRA
Appendix C

Subsurface Soil Investigations – Summary Table

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Appendix C. Subsurface Soil Investigations – Summary Table

Document	Area/Building(s)	AOIs Detected in Subsurface Soil
000-1 SEP AOC Closeout Report July 2003	Solar Ponds	Nitrate, Uranium
100-4 and 100-5 Closeout Report April 2003	Buildings 121 and 123	VOCs
300-1 Closeout Report June 2003	Oil Burn Pit No. 1 Building 335	VOCs
400-3 Data Summary Report December 2003	Buildings 444, 447, and 453, and associated OPWLs	VOCs
400-8 Closeout Report March 2004	Building 441 and associated OPWLs	VOCs, Nitrate
400-10 Data Summary Report July 2003	Sandblasting Area, Fiberglass and Radioactive Site west of Building 664	VOCs
500-1 Data Summary Report	Valve vaults 11,12,and 13, North Central Storage Site, Scrap Metal Storage Site	VOCs
500-2 Closeout Report June 2004	Building 551	VOCs
500-4 Data Summary Report June 2004	Middle Site Chemical Storage	VOCs
600-1 Closeout Report June 2003	Building 663	VOCs
600-3 Data Summary Report May 2004	Fiberglass area north of Building 664	VOCs
700-4 Notification/Closeout Report February 2004	Buildings 771, 774, and 776, and associated tanks and OPWLs	VOCs
800-1 Closeout Report March 2004	Buildings 865, 866, and associated tank and OPWL	VOCs
800-5 Data Summary Report July 2004	Buildings 887 and 885	VOCs
800-6 Closeout Report March 2003	Buildings 889 and 991	VOCs

(continued next page)

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(Appendix C continued)

Document	Area/Building(s)	AOIs Detected in Subsurface Soil
900-1 Closeout Report April 2004	Building 991	VOCs
900-3 Data Summary Report December 2003	904 Pad	VOCs Nitrate –Surface Only
900-4&5 Data Summary Report July 2003	Building 980	Nitrate –Surface
SW-1 Incinerator NFAA	Ash Pits 1,2, and 4, Incinerator	VOCs
NE/NW Buffer Zone Data Summary Report	East Spray Field, Pond B-2, East Trenches, PU&D Yard	VOCs

Notes:
AOC Area of Concern
AOI Analyte of Interest
NFAA No Further Accelerated Action
PU&D Property Utilization and Disposal
SEP Solar Evaporation Ponds
VOC Volatile Organic Compounds

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Groundwater IM/IRA
Appendix D

Modeling to Support Building Closure

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APPENDIX D. MODELING TO SUPPORT BUILDING CLOSURE

1.0 INTRODUCTION

In the anticipated physical completion of the Industrial Area (IA), portions of subsurface building structures will remain in several areas. These subsurface structures have the potential for impacting the local surface and groundwater hydrology since they extend below the shallow groundwater table. Issues discussed by the Colorado Department of Health and the Environment (CDPHE) and U.S. Environmental Protection Agency (EPA) about potential impacts to the local hydrology are graphically illustrated on Figure D-1. The first issue is whether groundwater levels increase behind basement walls ("1" on Figure D-1), or above basement slabs ("2" on Figure D-1), causing surface seeps to develop and subsequent ground surface slumping that exposes the basement structures. The second issue is whether the fate and concentration distribution of volatile organic compounds (VOCs) in groundwater ("3" on Figure D-1) is impacted by the subsurface structures.

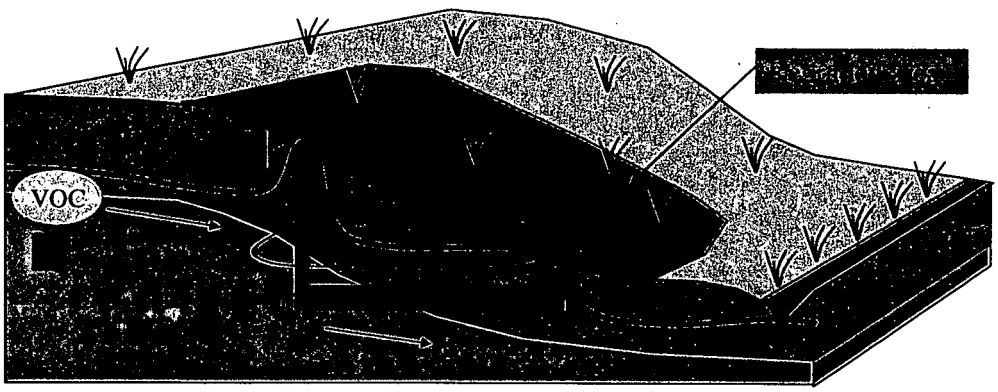

Figure D-1. Areas of Concern

The hydrologic response due to the anticipated IA physical completion, including leaving subsurface structures below grade, is complex. In areas where deep building basement structures are left in place, many factors influence groundwater levels and surface runoff. Previous integrated hydrologic analyses were conducted as part of the Site-Wide Water Balance (SWWB) modeling (K-H, 2002). That modeling demonstrated that the dynamic interaction between the surface flows and unsaturated and saturated zone flows, combined with climate dynamics, is essential for predicting the spatial and temporal hydrologic system responses over time. In addition, several IA features, such as subsurface utilities, drains, pavement, and buildings, further complicate the natural integrated system response which is dominated by features such as the depth to weathered bedrock and the spatial distribution of unconsolidated material and vegetation.

To evaluate the potential surface and groundwater impacts from remaining subsurface structures, an integrated hydrologic flow model was developed using the MIKE SHE code from the SWWB modeling (K-H, 2002). Specific areas evaluated with the integrated model include the following:

- Buildings 771 and 774 area;
- Building 371 area;
- Building 881 and 883 area; and

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- Building 991 area (including Building 991, the 996, 997 and 998 Vaults, and the 991 and 998 tunnels).

Despite obvious differences in hydrologic conditions within each model area, a general modeling approach was developed to evaluate the anticipated physical condition of the Site at completion. Details of this approach are described in Section 2.0. Section 3.0 provides a brief summary of the anticipated physical condition of the Site at completion and its influence on the hydrologic response of the system. A discussion of building-specific model simulations and results is presented in Section 4.0.

2.0 GENERAL MODELING APPROACH

Several steps were required to develop the four local-scale, high-resolution models to assess the hydrology of the anticipated physical condition at contract completion at each of the building areas. Although much of the model input and basic information used to develop the SWWB model is used to construct the local-scale integrated flow models for each building area, individual Geographic Information System (GIS) databases were prepared to refine the model grid resolution. Local-scale spreadsheet algorithms, linked to the model-specific GIS databases, were prepared to organize and automate input to each integrated model.

The numerical grid resolution for the saturated zone, unsaturated zone, and overland flow processes is 25-feet by 25-feet. This represents a significant increase in the model grid resolution compared with the original SWWB modeling (i.e., 200-feet by 200-feet). The reason for the increased resolution was to improve the ability of the models to simulate the subsurface structures left in place. The local-scale building models also required increased vertical numerical resolution to account for the anticipated physical features, remaining building structures, underlying gravel material, the weathered bedrock surface, and the three-dimensional distribution of Arapahoe sandstone. Because of the increase in horizontal overland flow resolution, explicit definition of surface channel flow, using the MIKE11 module, was not essential. Instead, overland flow was simulated based on the topographic surface and two-dimensional diffusive wave approximation in MIKE SHE.

Hydraulic properties for each integrated building-area model were obtained principally from the former SWWB model. However, several features required refinement from the original GIS coverages (e.g., all of the subsurface utility trenches originally obtained from engineering drawings and available information were rescaled to the refined 25-foot grid). Other model input information also had to be rescaled, including: (1) weathered and unweathered bedrock depths; (2) observed groundwater level distributions; (3) vegetation and soil distributions; and (4) impervious/pervious areas. Finally, engineering drawings were obtained for internal and external three-dimensional building structures so that groundwater flows within and external to the remaining building basements could be simulated as accurately as possible with the integrated model.

To simulate conservative flow conditions and water levels, a wet-year continuous climate sequence was considered. Initially, three consecutive 100-year, wet-year sequences, described in the SWWB modeling report (K-H, 2002) were used to stabilize initial conditions and obtain representative wet-year flow conditions and water levels. For building closure models, two typical climate years (based on Water Year [WY] 2000 climate data) were used to stabilize initial conditions, and a single wet-year, 100-year basis was used to simulate conservatively high groundwater levels and flows. In addition, preliminary simulations and discussions with CDPHE indicated that existing building footing drains would be simulated as disrupted so that conservatively high groundwater levels would develop surrounding remaining building structures. This would account for possible future failure (i.e., collapse and/or plugging) of existing footing drains.

Several simulated system responses were assessed for each model. For example, both the mean and minimum annual simulated groundwater depths were used to assess areas where groundwater levels are predicted to be near or above ground surface. Groundwater discharge rates, flow rates, and three-dimensional flow directions were also estimated for each model area. Lastly, an advection-dispersion transport module as part of the MIKE SHE code was used to assess impacts to the distribution of VOCs in groundwater in each model area. It should be recognized that because attenuation processes such as sorption, degradation, diffusion, and volatilization were not simulated, the transport modeling results are effectively used in a fashion similar to particle tracking codes, only to evaluate flow paths, but *not* actual concentrations. Specific details on assumptions made for the anticipated physical condition of the Site at completion are described in Section 3.0.

3.0 ANTICIPATED PHYSICAL CONDITION AT CLOSURE

Prior to developing the integrated flow models for each building area, detailed information on the proposed closure configuration was discussed with Environmental Restoration (ER) personnel. This section describes details associated with each assumption. It should be noted that, although similar to the closure configuration simulated in the SWWB modeling, there are several notable changes.

Each model area was defined large enough to avoid effects of boundary conditions on internal, near-structure hydrologic conditions. The areas were also selected so that appropriate surface and subsurface boundary conditions could be assigned so that unreasonable effects were prevented. Lastly, the model boundaries were selected so that transport of VOCs to nearby surface discharge areas could be assessed. In other words, model boundaries were generally associated with streams, so that the fate of VOCs in groundwater could be assessed more realistically.

Three-dimensional structural details of all building basement slabs, walls, vaults, and tunnels were obtained from available land reconfiguration engineering drawings (provided by ER). Where subsurface structures remained, a minimum of 3 feet of soil will remain below the regraded topography. Where basement structures, such as walls, extend above the regraded topography, they were removed to be 3 feet below final grade. Within the building basements, concrete rubble and/or fill material, with hydraulic properties similar to Rocky Flats Alluvium (RFA), will be placed above the concrete slab. Although difficult to estimate, the saturated hydraulic conductivity of the remaining subsurface concrete slab and walls was assumed to be low (i.e., 1×10^{-10} meters per second [m/s]). This permits the walls and slab to leak, but only at a slow rate, to simulate effects of leakage through cracks and joints in the structure.

Subsurface pipelines, including sanitary, storm, and building footing drains, process waste lines, and water supply lines were all assumed to be removed or disrupted. All subsurface utility trenches were simulated as remaining in place. These include the above drains as well as trenches associated with alarms, communications, natural gas, and electric. Therefore, the assumed more conductive backfill trench material was simulated as a preferential pathway, with higher conductivity than surrounding natural material.

A regrade topographic surface was provided by ER in a high-resolution file format. This surface includes both cut and fill areas. In areas where soil fill was added, the fill material was assumed to have similar hydraulic properties as the RFA. A fully established mesic-type vegetation was assumed over the entire regrade areas and in areas where pavement or buildings were removed. In areas where the topography remained unmodified, existing vegetation was assumed. Vegetation growth model input parameter values were obtained from the SWWB model vegetation database.

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4.0 MODELING RESULTS

Specific details of simulations run for each model and subsequent results are described in this section. The Building 771 area model is described first because this model was developed first, and initial simulations of current conditions were conducted to demonstrate that the rescaled model input reproduced observed groundwater levels and discharge rates adequately.

4.1 Building 771 Area Model

4.1.1 Building 771 Model Area - Model Details

The model area and 25-foot square grid are shown on Figure D-2. Specific buildings of interest in the Building 771 model area include Buildings 771 and 774 (shown on Figure D-2). The majority of the basement slabs and walls for these buildings remain based on the new regrade topographic surface. Building 771C, located between Buildings 771 and 774, will be removed entirely. Remaining subsurface support pilings associated with Building 776 and 777 structures located along the southern model boundary will not likely impact groundwater flows significantly and therefore were not considered explicitly in the model.

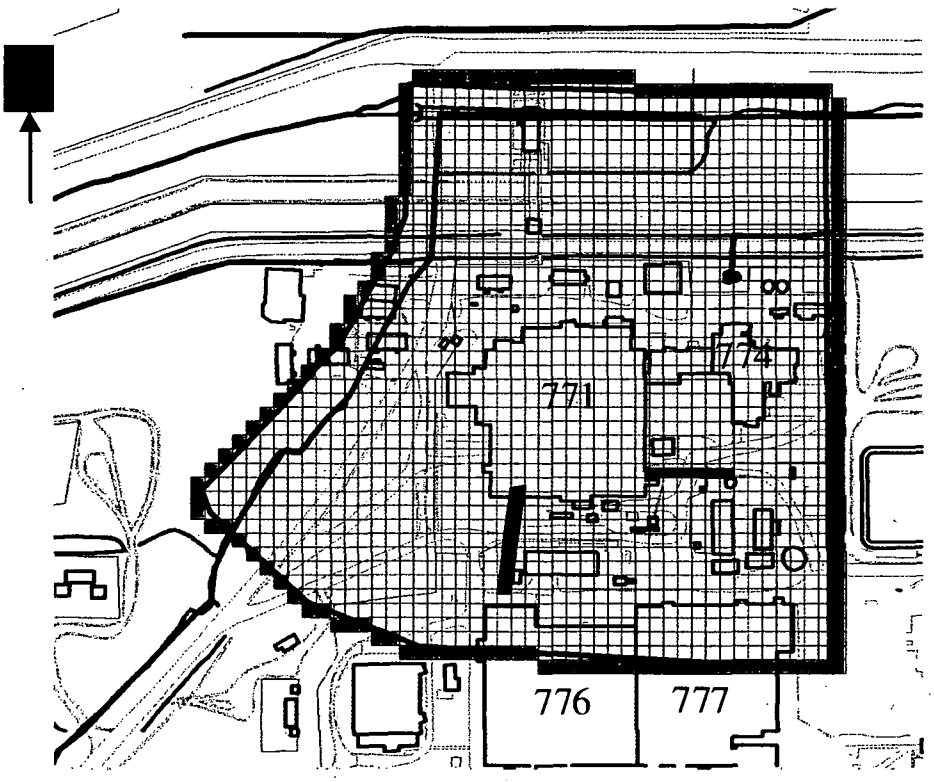

Figure D-2. Model Boundary and Boundaries of Interest – Building 771 Area Model

The integrated hydrology in the Building 771 model area is complex. Groundwater flow in the vicinity is three-dimensional and affected by several factors. Some of these include the Building 771 and 774 basement slabs and walls, Arapahoe Sandstone in the area, subsurface tunnels between Buildings 771 and

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776 and between Building 771 and the stack to the east, and the hillslope morphology west and north of Buildings 771 and 774.

The hydrologic impact of closure is of interest in several areas of the Building 771 model. For example, areas upgradient of the Building 771 basement walls (southern and southwestern edges) and upgradient of the Building 774 walls (southern) were of concern for groundwater level buildup. Also of interest was the potential for groundwater buildup immediately upgradient (east) of the Building 771/776 tunnel and upgradient (south) of the Building 771 stack tunnel.

Lateral boundary conditions were selected at sufficient distances to prevent impacts in the areas of interest. Channelized surface flow was simulated in the unnamed tributary to the west of Building 371 and in North Walnut Creek using MIKE 11. Simulated overland flow was generated by groundwater discharge to the surface flows into these channels.

The long-term (100-year) movement of the Carbon Tetrachloride Plume (Individual Hazardous Substance Site [IHSS 118.1]), south of Building 771, was simulated using an advection-dispersion module (a Danish Hydrologic Institute [DHI] code) that uses the integrated MIKE SHE flow model results. It does not simulate effects of degradation, diffusion, or sorption, but it accounts for most of the plume movement from the assumed source area. Therefore, transport modeling results overpredict concentrations, but this is reasonable for evaluating impacts of different scenarios on the Carbon Tetrachloride Plume because it is conservative. Effectively, the advection-dispersion module is used as a particle tracking tool to assess flow paths, but not concentrations.

4.1.2 Building 771 Area Model – Simulation Results

An integrated model of the current system configuration (WY 2000) was developed first to demonstrate adequate model performance with the grid refinement and rescaled model input data. Only minor adjustments to the current system configuration model input obtained from the former SWWB model (K-H, 2002) were required to obtain a reasonable comparison between simulated and observed hydraulic response. Average annual groundwater levels from available wells in the area were compared against simulated average annual groundwater levels. Average annual simulated groundwater levels are well within 3 feet of observed values. The model also reproduced the observed average annual foundation drain discharge rates well, ranging between 10 to 20 percent of reported values.

For a typical climate (WY2000), the closure configuration model showed that average annual water levels remained well below 3 feet below grade within and surrounding most of Buildings 771 and 774. Along the northern slab boundary, average annual groundwater levels were within 1 meter of ground surface because of lateral drainage off of the slab and the shallow bedrock in the area. Several simulations were conducted to assess the sensitivity of groundwater levels along the northern boundary to assumed model input parameter assumptions. Adjustments in hydraulic conductivity, the annual climate sequence, subsurface drain conductance, and holes in the slab and wall were evaluated.

Results from the sensitivity simulations showed that a 100-year wet-year climate sequence (K-H, 2002) combined with deactivated drains (conservative model) caused significant increases in average annual groundwater levels around Building 771 compared to average conditions for the case described above. Drilling holes in the slab floor caused groundwater levels to increase only approximately 0.5 meters above the slab. Assuming the Arapahoe Sandstone was not present in the model only causes slight increases in groundwater levels upgradient of Buildings 771 and 774.

Simulated mean and minimum annual groundwater depths for the conservative model assumptions (i.e., wet-year climate and no foundation drains) are shown on Figures D-3 and D-4, respectively.

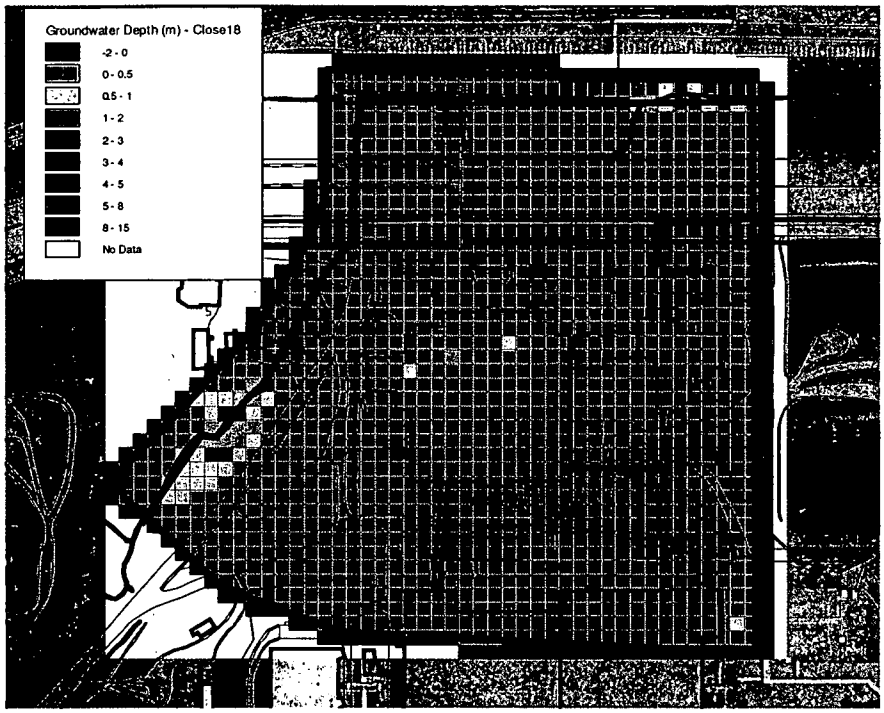

Figure D-3. Simulated Mean Annual Groundwater Depths (m) - Wet Year, No Footing Drains

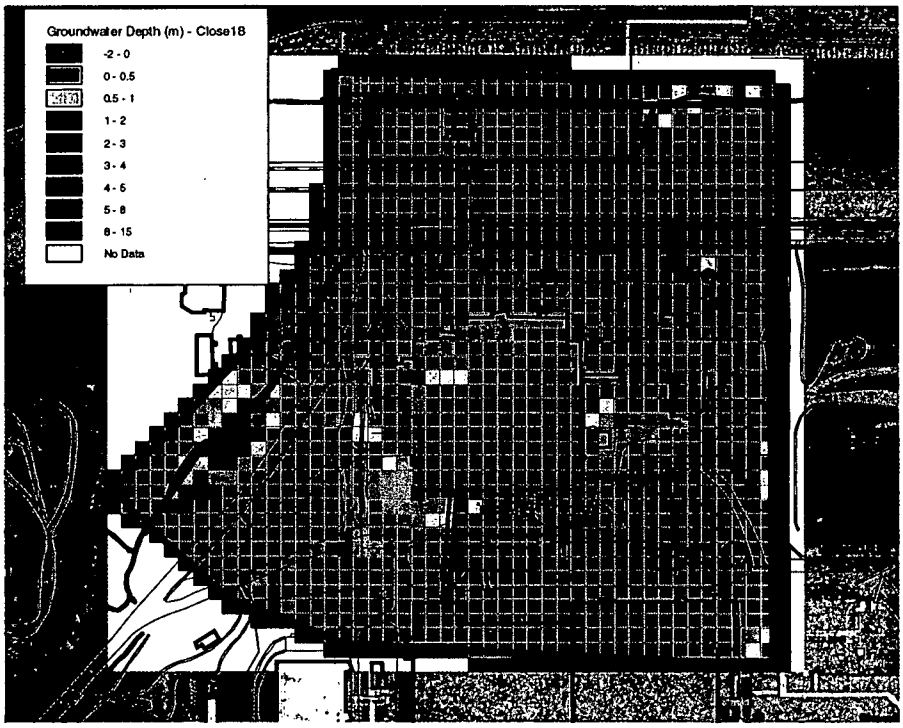

Figure D-4. Simulated Minimum Annual Groundwater Depths (m) - Wet Year, No Footing Drains

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Results displayed on Figure D-3 and Figure D-4 show that average annual groundwater levels upgradient of the remaining Building 771 walls remained more than 1 meter below ground surface. Simulated closure configuration water levels did not build up upgradient of either of the two tunnels (Building 771 to 776 tunnel or Building 771 to east stack tunnel). However, for larger precipitation events during the wet year, groundwater intercepts the ground surface along the upgradient, or southern and eastern Building 771 basement walls. This is caused both by the remaining basement wall, but also by shallow bedrock and deactivated foundation drains in these areas. Results also indicated that average annual groundwater levels rose above ground surface along the northern edge of the slab for Building 771, where depths below the regrade surface topography were approximately 1 meter.

Average annual groundwater flow directions are shown for unconsolidated materials and the weathered bedrock model layers on Figure D-5. Simulated flow directions for the two layers are similar, although flows immediately upgradient of subsurface structures were locally forced to flow around or beneath them. Groundwater that built up above the building slabs in both Buildings 771 and 774 flowed directly north because of the remaining eastern and western basement walls. Groundwater discharge from the building slabs flowed north-northeast and eventually discharged to North Walnut Creek.

Figure D-5. Simulated Average Annual Groundwater Flow Directions – Unconsolidated Material and Bedrock, Respectively

The advective-dispersive transport simulation results are illustrated on Figure D-6 for unconsolidated material and the weathered bedrock model layers (concentrations are in parts per billion [ppb]). From the Carbon Tetrachloride Plume source south of Building 771, contaminants flow downward and into the weathered bedrock and gravel layer underlying the Building 771 slab. As the contaminants flow north-northeast from Building 771, upward groundwater gradients force the contaminants back up into the unconsolidated material, where they flow preferentially toward North Walnut Creek. It should be recognized that this simulation only demonstrates where contaminants would flow after 200 years; natural attenuation processes such as degradation and sorption would reduce actual concentrations notably.

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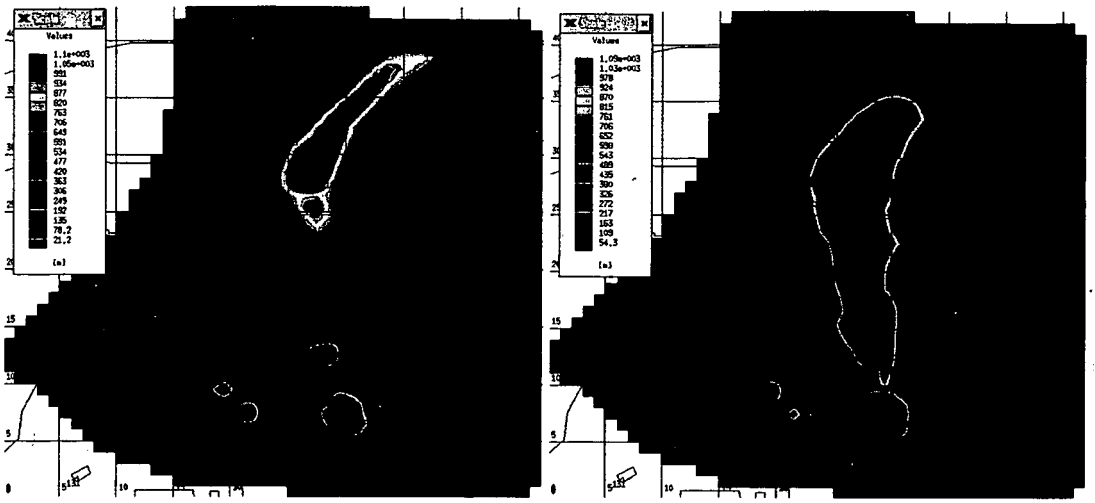

Figure D-6. Simulated PCE Groundwater Distribution After 200 Years

4.2 Building 881 Area Model

4.2.1 Building 881 Model Area – Model Details

Basement slabs and walls associated with Buildings 883 and 881 were included in the Building 881 area model. Figure D-7 shows the integrated flow model area, numerical grid, and boundary cells aligned with Woman Creek to the south. Boundary cells were defined far enough away from the 881 and 883 Buildings to prevent impacts to these areas. This is reasonable given that groundwater levels within the IA typically respond more to direct recharge and evapotranspiration (ET) (K-H, 2002) than to lateral inflow conditions (i.e., constant head cells along boundary).

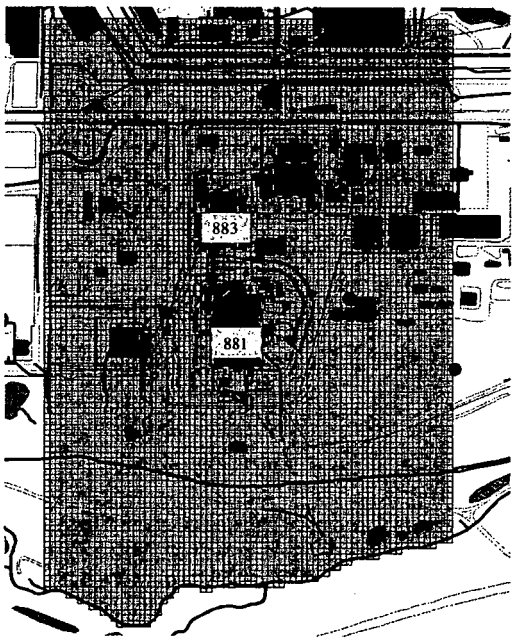

Figure D-7. Model Boundary and Buildings of Interest – Building 881 Area Model

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Engineering drawings of subsurface basement walls and slabs for Buildings 881 and 883, combined with discussions with ER personnel, were used as the basis for developing two closure scenarios. Based on the regrade topography provided, the entire Building 881 slab remained intact, while portions of the basement walls to the south were removed to within 3 feet below the new topographic surface. Although Building 883 does not extend as deep below grade as Building 881, most of its subsurface basement slab and portions of the walls remained. It is important to recognize that subsurface slab elevations for both Buildings 881 and 883 were spatially variable within each building footprint.

Little Arapahoe Sandstone occurs within this model area, although the weathered bedrock surface and surface regrade topography dominated groundwater flow paths within the area. As a result, under current conditions, groundwater south of Building 881 flowed south toward Woman Creek, while north of Building 881 groundwater flows in a more easterly direction, consistent with the topographic and bedrock surface gradient directions.

Hydrologic conditions for two closure scenarios were evaluated using the integrated flow model for the Building 881 area. The first scenario assumed that all vertical walls for Building 881 were impermeable, while the second scenario assumed that the northern and southern walls were permeable. There were two reasons for simulating these scenarios. The first was to evaluate whether groundwater levels within and surrounding Building 881 would be reduced significantly by using permeable walls. The other reason was to evaluate whether impermeable walls reduce potential southern migration of a VOC plume immediately west of Building 883.

4.2.2 Building 881 Model Area – Closure Configuration Simulation Results

Simulated mean and minimum annual groundwater depths below the proposed closure regrade topography for the wet-year climate sequence for the impermeable wall scenario are shown on Figure D-8. Selected grid cells denote areas predicted by the model where groundwater depths are less than 1 meter below grade. The simulated depths are calculated for a single 100-year basis annual wet-climate sequence following two typical climate years (WY2000) to stabilize initial saturated and unsaturated zone flow conditions.

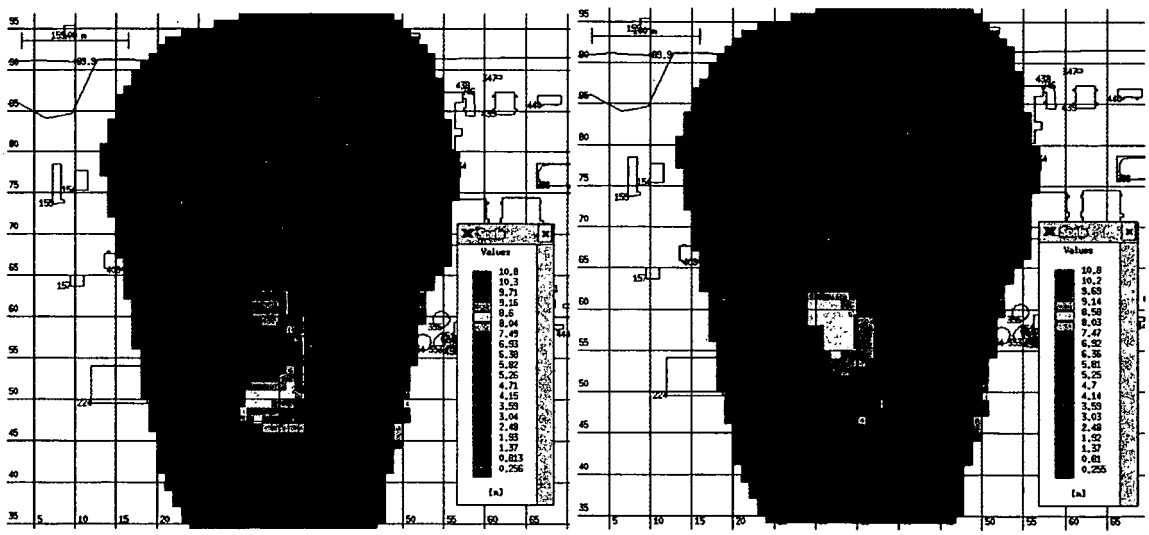

Figure D-8. Mean and Minimum Annual Groundwater Depths (m) - Impermeable Wall Scenario

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Results indicate that simulated closure groundwater depths surrounding Building 881 are well below 1 meter for both cases, but more so for the case using permeable walls. This reduces the potential for slumping and possible exposure of the structure, particularly along the hillslope to the south. In both cases, groundwater depths decreased towards the northern and eastern model areas because of thinning unconsolidated material thicknesses. Simulated groundwater depths also decreased to less than 1 meter toward Woman Creek in response to the hillslope structure and thinning unconsolidated materials near the creek. Depths did not build up within and above the Building 881 slab because the slab is more than several meters below the regrade topography.

Although groundwater depths decreased upgradient and within Building 881 compared to the scenario where the walls are permeable, they remained well below a depth of 1 meter below the proposed grade. Groundwater depths immediately north of the remaining Building 883 basement structure were also less than 1 meter, but did not pose a problem with slope stability given the relatively flat regrade topography in this area.

Simulated groundwater flow directions above and below basement slabs for Buildings 881 and 883 are illustrated on Figure D-9.

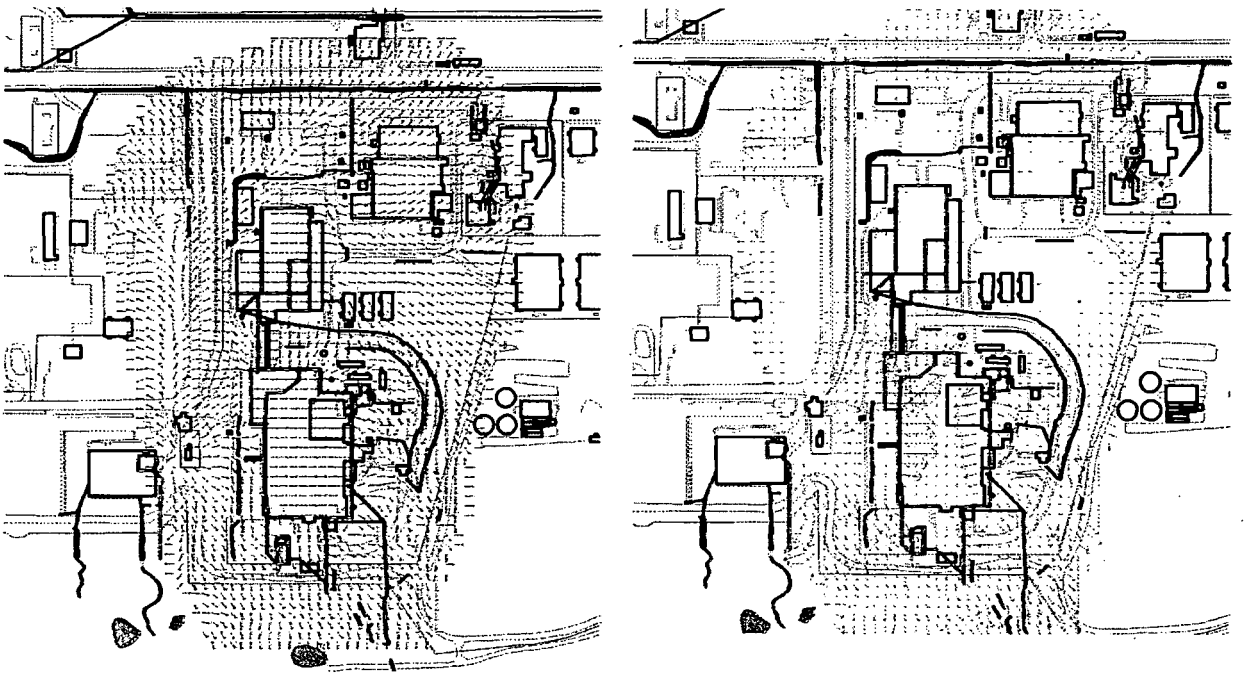

Figure D-9. Simulated Groundwater Flow Directions, Above and Below Slab, Respectively

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Results of an advective-dispersive transport simulation of a tetrachloroethene (PCE) Plume Signature Area (PSA) located west of Building 883 are shown on Figure D-10.. Results are shown for the impermeable wall scenario. For an permeable wall scenario (with permeable northern and southern Building 881 walls), results showed PCE migration would be southward, rather than eastward and northward as shown for the impermeable wall scenario shown on Figure D-10. It should also be recognized that maximum simulated PCE concentrations are less than the currently proposed surface water Preliminary Remediation Goals (SWPRGs).

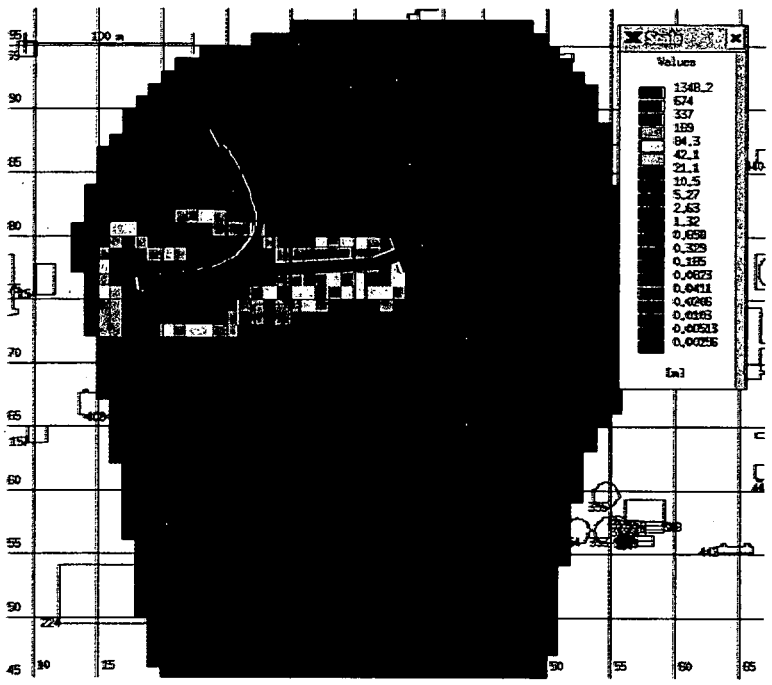

Figure D-10. Simulated PCE Groundwater Distribution After 200 Years

As a result of the Building 881 area modeling, it was recommended that Building 881 walls and slab should not be made more permeable, thereby preventing southward migration of VOCs west of Building 883. The subsurface structure associated with Building 883 appears to pose no problems with respect to groundwater levels or transport. However, it was recommended that the footing drains between Buildings 883 and 881 be disrupted to prevent possible pathways for southward migration of PCE intercepted near Building 883.

4.3 Building 991 Area Model

4.3.1 Building 991 Area Model – Model Details

A localized, high-resolution integrated flow model was developed for the area associated with the Building 991 Corridor C Tunnel and Vaults 996, 997, and 999 (Figure D-11). The integrated Building 991 area flow model also includes Building 991, 998 Vault, and Buildings 984 and 985. The purpose of the refined model was to better simulate localized hydraulic conditions surrounding the Building 991 structures proposed to be left in place under conservative wet-climate conditions. The need to accurately

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model the local conditions was in response to concerns about groundwater levels building up behind structures left in place, which then might cause surface erosion and possible slumping, particularly along the southern hillslope to South Walnut Creek.

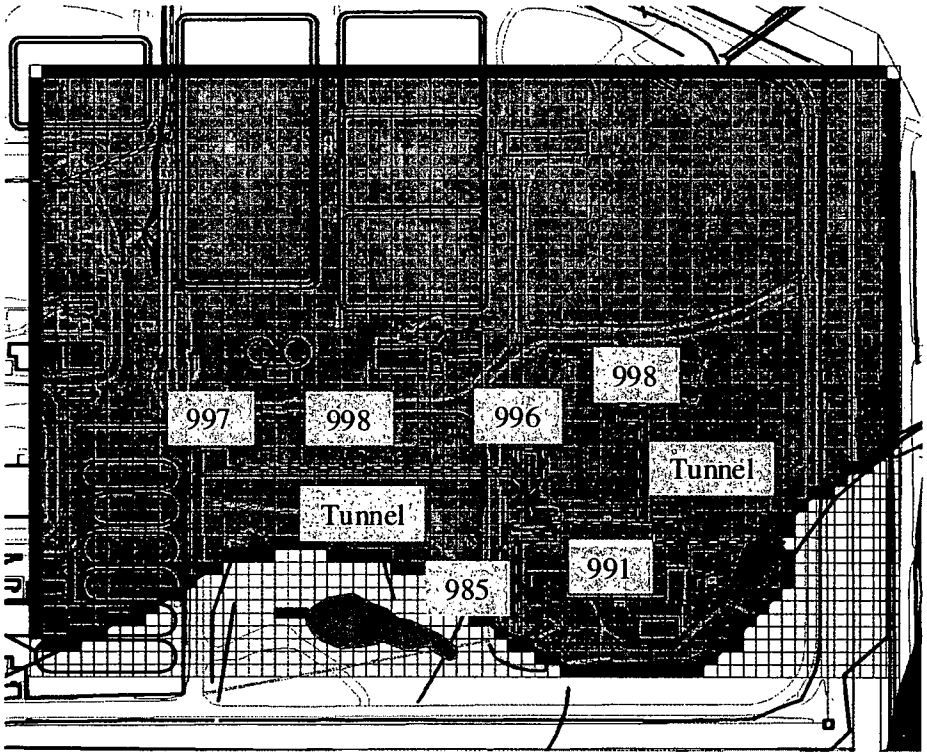

Figure D-11. Model Boundary and Buildings of Interest – Building 991 Area Model

A grid resolution of 25 feet was developed for the saturated, unsaturated, and overland flow processes in the integrated model. Surface channel flow was not explicitly simulated in the model because it does not impact the hydrologic conditions within the Building 991 area, and the hydrologic response in South Walnut Creek was not of concern. An appropriate set of overland flow (non-channelized) and saturated zone boundary conditions were specified along the southern model boundary that coincides with South Walnut Creek.

Specific closure conditions for the Building 991 structures, combined with other land configuration modifications, were provided by ER. For example, the entire subsurface structure associated with Building 984 was assumed removed for closure. Left in place were the 991 Tunnel; Vaults 996, 997 and 999; and the 998 Vault were to be left in place. Based on the regrade surface topography, only portions of Building 991 and the 998 Tunnel structures required being removed to maintain a distance of at least 3 feet between the structure left in place and the regraded surface level.

Hydraulic conditions surrounding the tunnel system were evaluated using conservative conditions. In other words, any conditions that lead to higher groundwater levels in the area were considered. The two primary conservative conditions included: 1) assuming a wet-year climate, and 2) assuming that current drains (upgradient of the 991 Corridor C Tunnel, Building 991, and the 998 Tunnel) in the area are not operaable. The Tunnel structures were assumed to have a low hydraulic conductivity (1×10^{-10} m/s) to simulate the effect of likely leakage through joints and cracks in the concrete. Although it was not

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possible to explicitly model flow within tunnel/vault voids given the grid resolution, flows were controlled in the area by the assumed effective concrete structure hydraulic conductivity. Fill material placed inside Building 991, as well as that used to regrade fill areas, was assumed to have hydraulic properties similar to the RFA material.

4.3.2 Building 991 Area Model – Closure Configuration Simulation Results

Simulated mean and minimum annual groundwater depths in the Building 991 area model for a wet-year are shown on Figures D-12 and D-13, respectively. Results indicate that average annual groundwater depths during the wet year remained below 1 meter for the entire eastern portion of the Building 991 area structures. However, depths were within 1 meter along South Walnut Creek, at the western end of the 991 Corridor C Tunnel, and near the former Solar Ponds where bedrock is shallow. This was further confirmed by simulating conditions without the 991 Tunnel. Virtually no difference occured in simulated groundwater depths for larger precipitation events. Minimum annual groundwater depths shown on figure D-12 shows that groundwater levels will reach the regrade surface topography in these areas. Minimum depths near the eastern Building 991 structures remained deeper, ranging from 3 to 5 meters. Greater depths occurred to the east because of increased depths to bedrock and the occurrence of Arapahoe Sandstone that immediately subcrops the unconsolidated material and extends northeast.

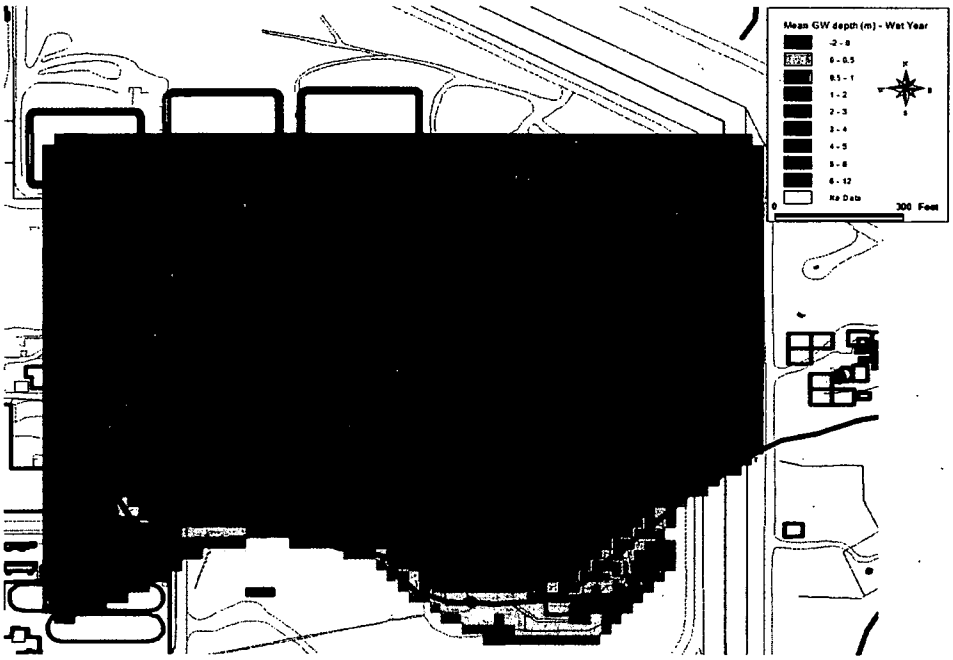

Figure D-12. Simulated Mean Annual Groundwater Depths (m) - Wet Year, No Footing Drains

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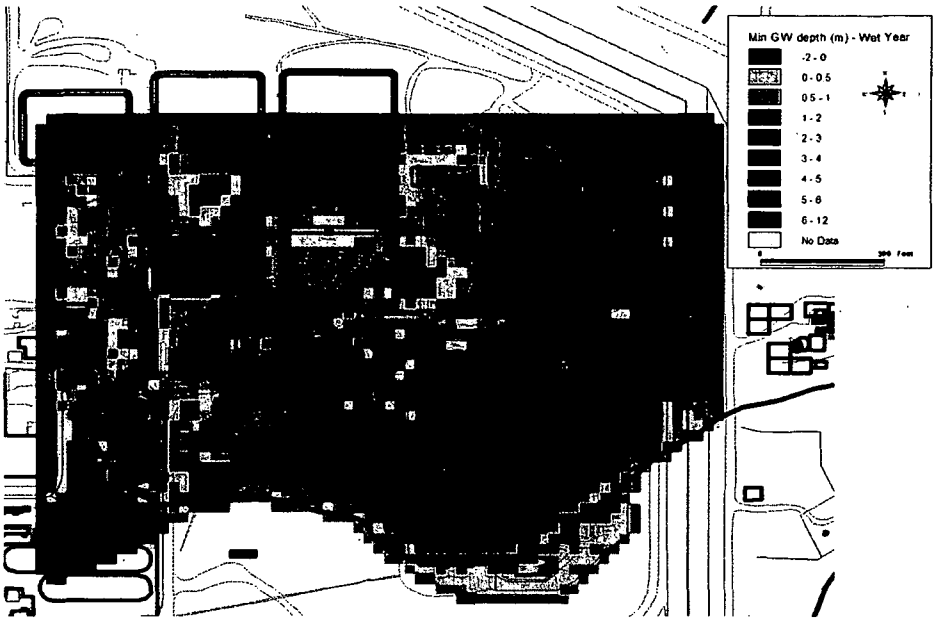

Figure D-13. Simulated Minimum Annual Groundwater Depths (m) - Wet Year, No Footing Drains

Simulated groundwater flow directions within the unconsolidated material are shown on Figure D-14. Results show that groundwater flows were affected by the remaining subsurface structures, but the effects remained localized. Although groundwater flowed southward over the 991 Tunnel, this was because the tunnel structure occurs entirely within the weathered bedrock, except for the 997, 999, and 996 Vaults that span a greater vertical extent. As flows reached the 991 Building wall and 998 Tunnel area, they were directed east and downward, enhanced by the gravel layer simulated below the remaining slab. Groundwater south and east, downgradient of the Building 991 structures, flowed directly toward the regraded Woman Creek channel.

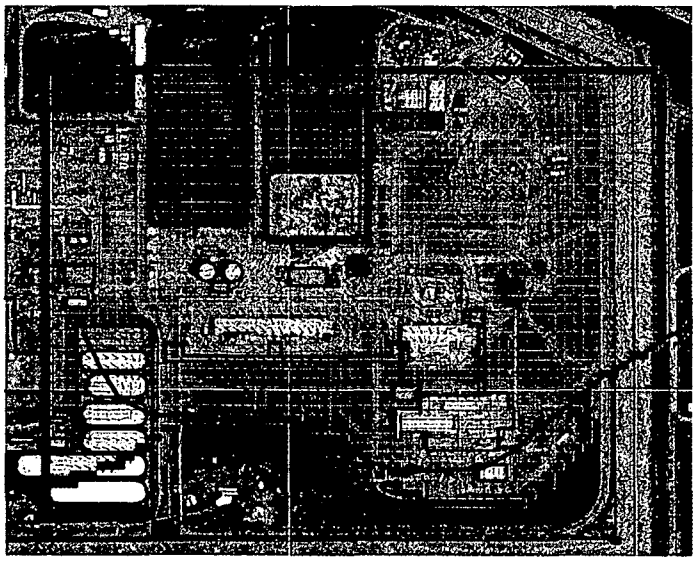

Figure D-14. Simulated Groundwater Flow Directions – Unconsolidated Material

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Transport simulations showed that VOC plume movement from the north into the Building 991 area did not occur due to the local northerly flow direction in the plume area (Figure D-15). Other detectable concentrations in some wells north and northeast of the Building 991 area were low and showed no clear association with known sources or historical releases in the area. Moreover, groundwater flow paths shown on Figure D-14 confirmed a more easterly flow direction in this area.

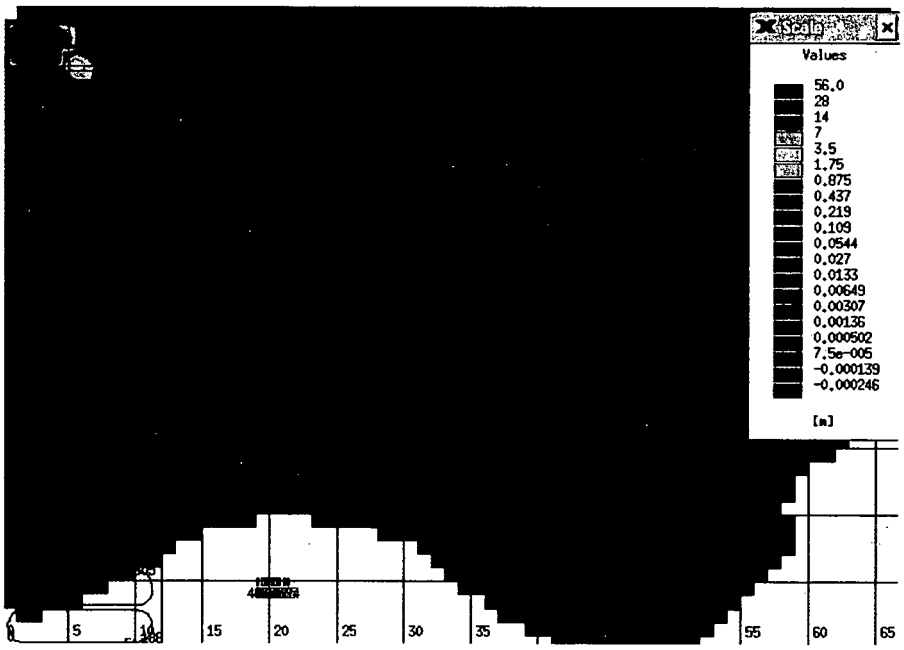

Figure D-15. Simulated Advective-Dispersive Transport of VOCs – After 200 Years

4.4 Building 371 Area Model

4.4.1 Building 371 Area Model – Model Details

The model boundary for the Building 371 area is shown on Figure D-16. The model boundary includes the entire Building 371 structure. Boundaries to the north and east were selected to coincide with North Walnut Creek and the unnamed tributary between Buildings 371 and 771, respectively. Boundaries to the south and west were selected far enough upgradient of the Building 371 area to prevent influence on internal calculations.

Arapahoe Sandstone is present only in the southern portion of the model area and does not influence the local hydrologic conditions around Building 371. Instead, as in other models, the weathered bedrock and topographic surfaces dominate the flow directions and potential buildup of groundwater levels in the model area. Available information indicate that the regrade topography shown on Figure D-16 shows a borrow pit area west of Building 371 that intercepts the weathered bedrock surface through the lower, more northern portion. The regrade topography also results in shallow bedrock depths in the area north of Building 371.

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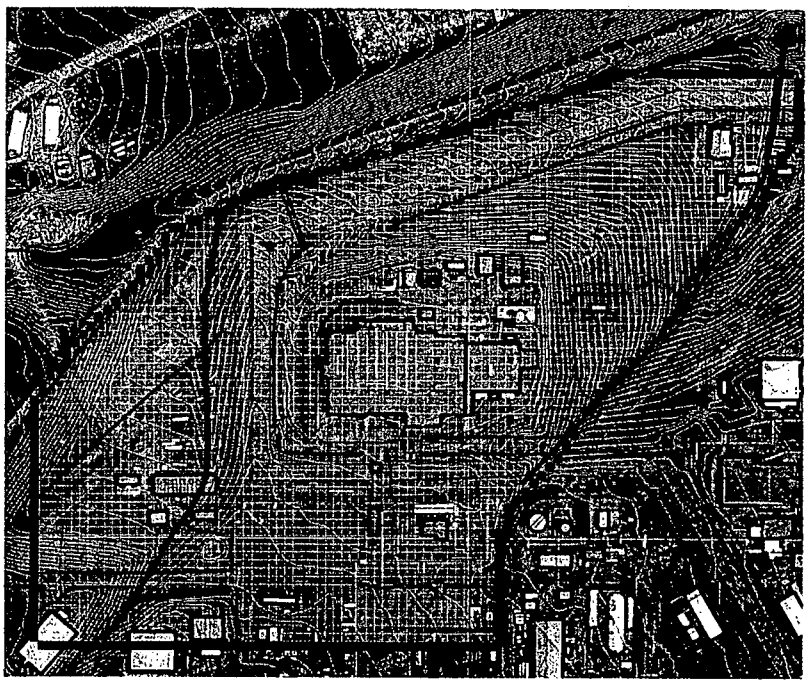

Figure D-16. Model Boundary and Buildings of Interest – Building 371 Model Area

Two surface water routing configurations were initially evaluated in the Building 371 area model. Simulated groundwater levels were slightly lower for the case where a channel is routed west of the Building 371 area. As such, only simulated closure configuration response with this surface channel routing is described here. The simulated flow channels considered in the Building 371 area model are also shown on Figure D-16.

The integrated hydrologic system responses for two scenarios were evaluated in the Building 371 area model. The first scenario simulated hydrologic conditions assuming permeable basement walls, while the second scenario simulated the walls as impermeable. An additional simulation was run to evaluate the impacts to flow and groundwater levels resulting from 25-foot wide access truck access holes in the northern, western, and eastern walls. Finally, an adective-dispersive transport simulation was run to assess long-term potential VOC transport from a PSA (13) located south of Building 371.

4.4.2 Building 371 Area Model – Closure Configuration Simulation Results

Simulated minimum annual groundwater depths for the permeable and impermeable basement wall scenarios for a wet year, with inactive building footing drains, are shown on Figures D-17 and D-18, respectively. The simulated groundwater depths effectively reflect conditions associated with the wettest part of a 100-year wet year. Results indicate that groundwater depths are notably shallower (0 to 1 m below grade) within and immediately upgradient of the Building 371 area for the impermeable wall scenario. Despite shallow depths in this area, the potential for slumping is limited due to the relatively flat topography upgradient of Building 371.

In both scenarios, groundwater depths range from 1 to 2 meters below grade immediately north of Building 371, where the hillslope grade begins. Along the hillside to the north and within the borrow pit, where bedrock is shallow, groundwater levels are predicted in the model to exceed the ground surface during a wetter period of a wet year. Model simulations with truck access holes in the northern, eastern

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and western walls indicate that groundwater levels actually decrease slightly within the building foot print as they equilibrate with external water levels.

Simulated average annual groundwater flow directions are shown for the impermeable wall scenario on Figure D-19 for unconsolidated materials. Groundwater flow vectors denote only flow directions, and do not define flow magnitude. Generally, groundwater flows toward the nearest surface channel, including the diversion west of Building 371, the channel between Buildings 371 and 771, and Walnut Creek to the north. As groundwater nears the impermeable basement walls of Building 371 from the south, it diverges to the west and east around the building and to the north within the subslab gravel layer.

Results of the advective-dispersive transport simulation of vinyl chloride (VC) south of Building 371 after 200 years, for the impermeable wall scenario, are shown on Figure D-20. Although these results suggest it is possible for contaminants to reach Walnut Creek and the unnamed tributary to the west of Building 371, it is unlikely due to the different attenuation processes not simulated here. When these attenuation processes (e.g., biodegradation, sorption, and diffusion) are simulated, VC degrades rapidly, mostly via aerobic degradation.

References:

K-H, 2002. Site-Wide Water Balance Modeling Report for the Rocky Flats Environmental Technology Site. May.

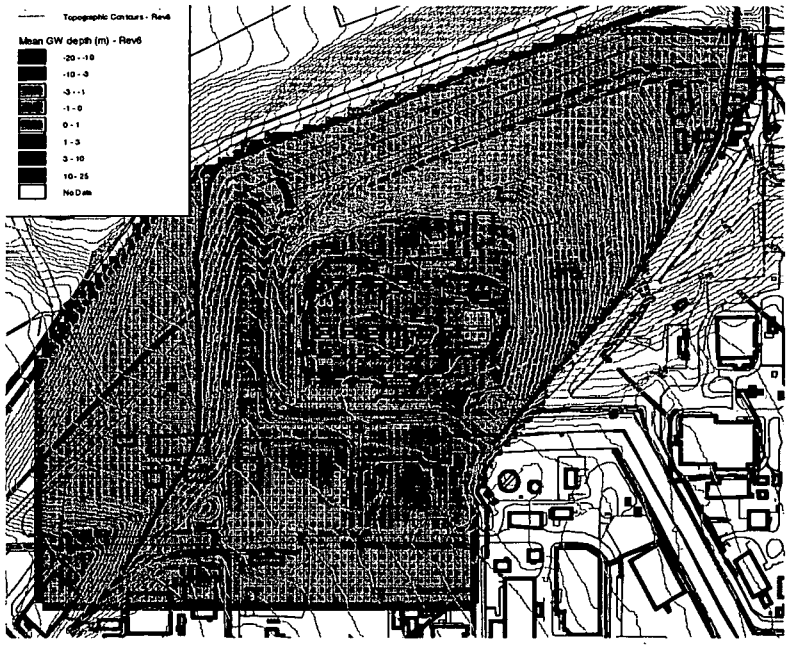

Figure D-17. Simulated Minimum Annual Groundwater Depths (m) - Permeable Wall Scenario, Building 371

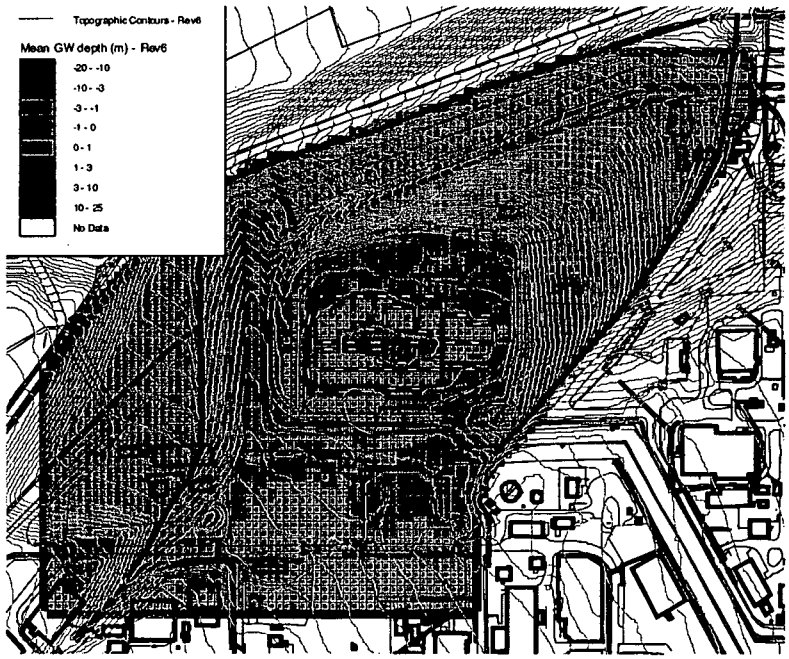

Figure D-18. Simulated Minimum Annual Groundwater Depths (m) - Impermeable Wall Scenario, Building 371

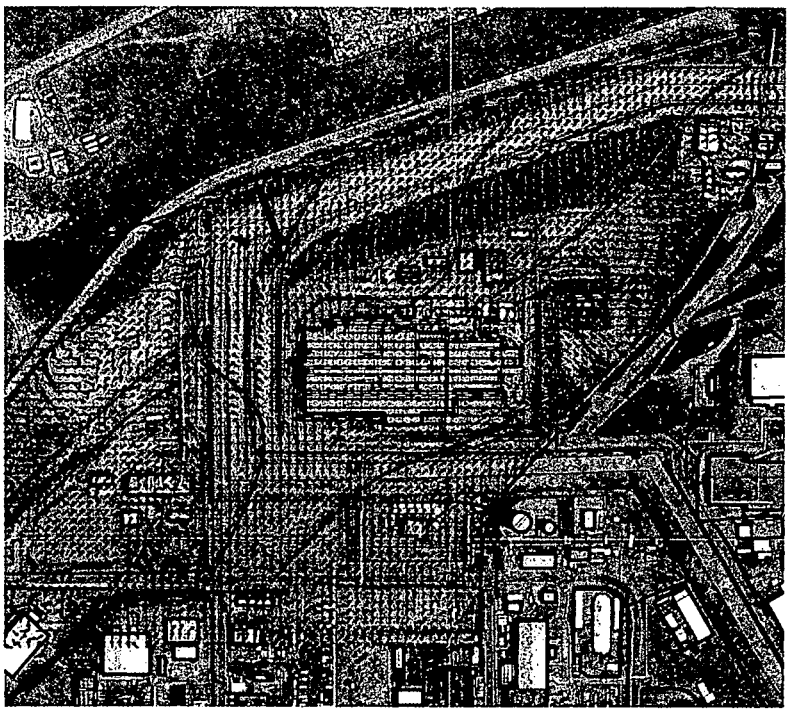

Figure D-19. Simulated Average Annual Groundwater Flow Directions – Unconsolidated Material

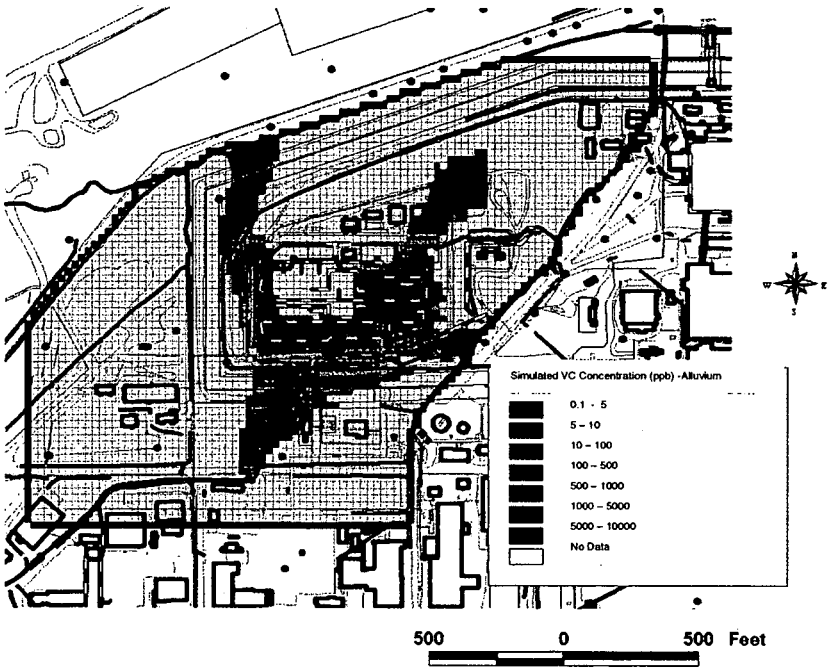

Figure D-20. Simulated Advective-Dispersive transport of VOCs – after 200 years

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Groundwater IM/IRA
Appendix E

Revised Model Results for Plume Signature Areas 5 and 12

PSA 5 – Mound Site/Oil Burn Pit #2
- Plots for TCE, PCE

PSA 12 – Central IA
- Plots for TCE and Carbon Tetrachloride

APPENDIX E - REVISED MODEL RESULTS FOR PLUME SIGNATURE AREAS 5 AND 12

1.0 GROUNDWATER FLOW AND TRANSPORT - CLOSURE CONFIGURATION WITH AMENDED TOPOGRAPHY FOR PLUME SIGNATURE AREA 5 AND PLUME SIGNATURE AREA 12

The results of the reactive transport models for Plume Signature Area (PSA) 5 (Mound Site/Oil Burn Pit #2 Groundwater Collection System Area) and PSA 12 (Central Industrial Area [IA]) that incorporate the revised ground surface topography of the proposed closure configuration conditions are included in this report. The groundwater flow fields from the MIKE SHE integrated model results were used for the transport models.

Steady, long-term concentrations were estimated at groundwater discharge locations downgradient of inferred volatile organic compound (VOC) source areas for each PSA model. Because of the uncertainty in model input parameters that affect the fate and transport of VOCs in groundwater at the Rocky Flats Environmental Technology Site (RFETS), multiple simulations were run to generate a range of possible long-term, steady concentrations at possible groundwater discharge locations. Ten closure configuration simulations were run to estimate the range of concentrations at groundwater discharge locations (Table E-1). Key flow and transport model parameter values were varied based on ranges determined in the sensitivity analysis of historical transport modeling (K-H, 2004). Simulations were conducted for both the tetrachloroethene/trichloroethene (PCE/TCE) and carbon tetrachloride (CT) degradation chain compounds at PSA 12 and for the PCE/TCE compounds at PSA 5. CT was not modeled at PSA 5 because observed concentrations were below the draft surface water preliminary remediation goal (SWPRG) value (0.58 milligrams per liter [mg/L]). The overall modeling approach and a detailed discussion of the inferred sources can be found in the in Fate and Transport Modeling of Volatile Organic Compounds (K-H, 2004).

Table E-1. Sensitivity Simulation Summary.

Sensitivity Simulation	Rationale
Base case	Represents a base case. Parameters in subsequent models were varied from this model.
Low sorption	Produces conservatively high concentrations downgradient.
Low dispersivity	Produces conservatively high concentrations downgradient. Reduces lateral and vertical concentrations. Increased likelihood of higher concentrations reaching discharge locations.
High dispersivity	Produces comparatively lower downgradient concentrations. Simulated concentrations located off the primary flow path (lateral and vertical) were higher.

(table continued)

(Table E-1 continued)

Sensitivity Simulation	Rationale
Low porosity	Produces lower downgradient concentrations. Less time for degradation. Increased likelihood of higher concentrations reaching discharge locations. Larger area of high overall concentrations for a constant source.
High porosity	Produces lower downgradient concentrations. Contaminants travel slower over a given time period. More time for degradation to attenuate transport.
Low source concentrations	Produces lower downgradient parent product concentrations. Lower concentration of parent (source) also gives lower concentration of daughter compounds.
High source concentrations	Produces higher downgradient parent product concentrations. Higher concentration of parent (source) also causes higher concentration of daughter compounds.
Low degradation rates	Produces higher parent product concentrations downgradient. Daughter product concentrations are lower down-gradient. Can be less conservative with respect to daughter products. Differs by PSA and VOC.
High degradation rates	Produces lower downgradient parent concentrations, but can increase daughter product concentrations. Depends on factors that control groundwater velocity and relative parent/daughter compound degradation rates. Differs by PSA and VOC.

1.1 PSA 12 (Central IA)

The PSA 12 model area includes Buildings 551, 559, and 371. Runs were simulated for 150 years to establish steady, long-term concentrations with time at the PSA extent along the stream located between Building 371 and 771.

Simulated long-term CT and TCE groundwater concentrations at simulated discharge locations along the tributary in the northwestern model area are summarized on Figures E-1 and E-2, respectively. The bar charts show the long-term simulated closure-condition groundwater concentrations at select discharge locations for each of the 10 simulations. None of the simulated discharge areas along the South Interceptor Ditch (SID), or Woman Creek, had a simulated concentration higher than the draft SWPRGs for PCE, TCE, or CT. Steady-state simulated concentrations ranged from 0 to a maximum of approximately 0.025 mg/L for TCE and CT.

1.2 PSA 5 (Mound Site/Oil Burn Pit #2 Groundwater Collection System Area)

Runs were simulated for 150 years to establish steady, long-term concentrations with time at the PSA extent along South Walnut Creek to the north and northwest. The average simulated groundwater concentrations of TCE and PCE for each of the model runs at integrated flow model groundwater discharge areas are shown on Figures E-3 and E-4, respectively. The bar charts show long-term simulated closure-condition groundwater concentration for each of the 10 simulations at select discharge locations. The average simulated PCE concentration (of the 10 sensitivity runs) was above the draft SWPRG (0.141 mg/L]) at several discharge locations along a section of the southern tributary of South Walnut Creek (Figure E-4). The average simulated TCE concentration was below its draft SWPRG (0.19 mg/L) at all simulated

discharge locations (Figure E-3). Two main factors contributed to the high simulated discharge concentrations: 1) the inferred VOC source (Oil Burn Pit #2), located west-northwest of the Mound trench source, and 2) Arapahoe Sandstone that subcrops immediately west of the Mound trench source and the modeled Oil Burn Pit #2 source. The relatively high-conductivity Arapahoe Sandstone may preferentially direct VOCs toward South Walnut Creek. The simulated concentrations using the topography of the new proposed closure configuration were less than those using the original topography.

Reference:

K-H, 2004. Fate and Transport Modeling of Volatile Organic Compounds, Kaiser-Hill Company L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado, April 2004.

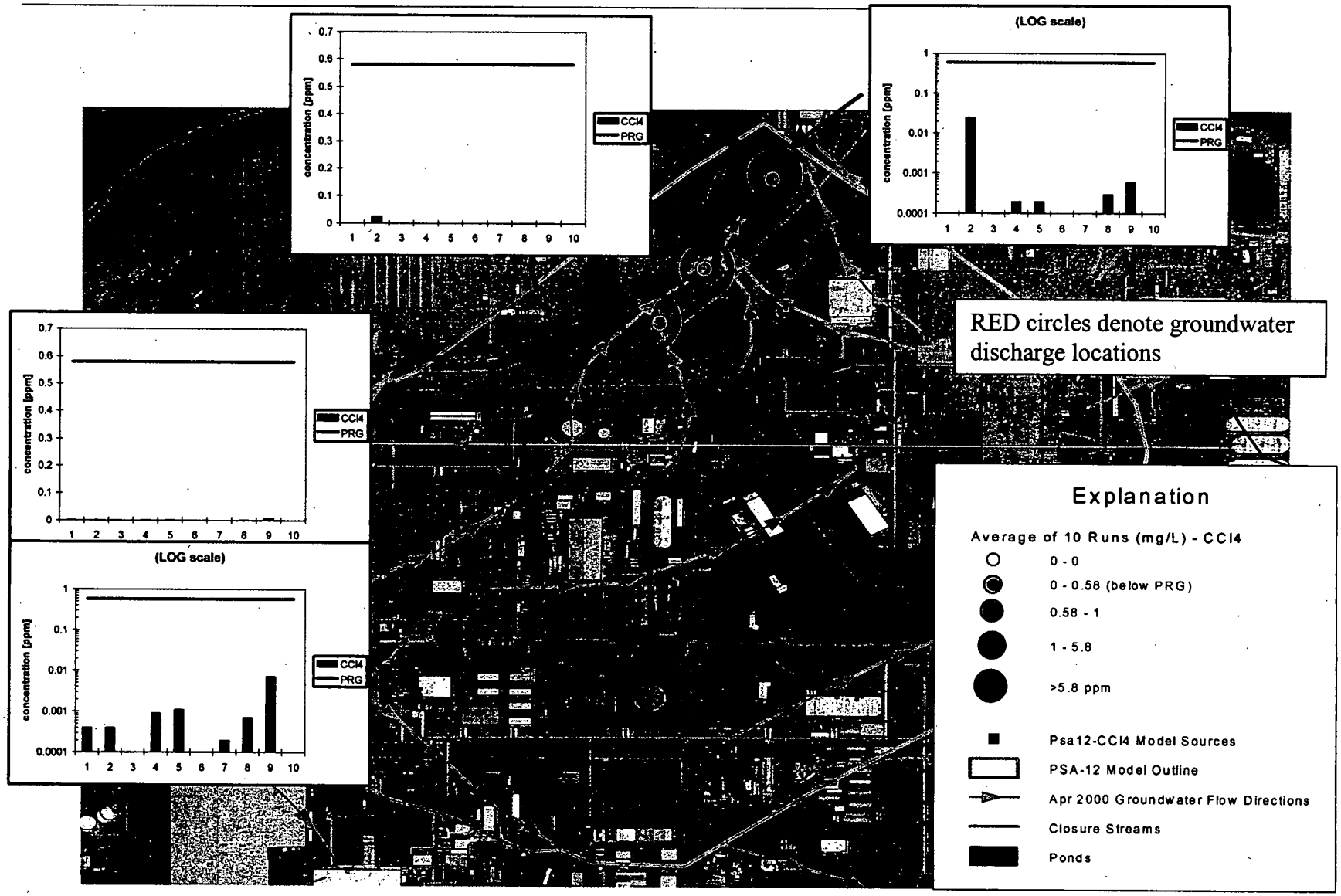

Figure E-1. PSA 12 – Simulated CT Groundwater Concentrations at Discharge Cells

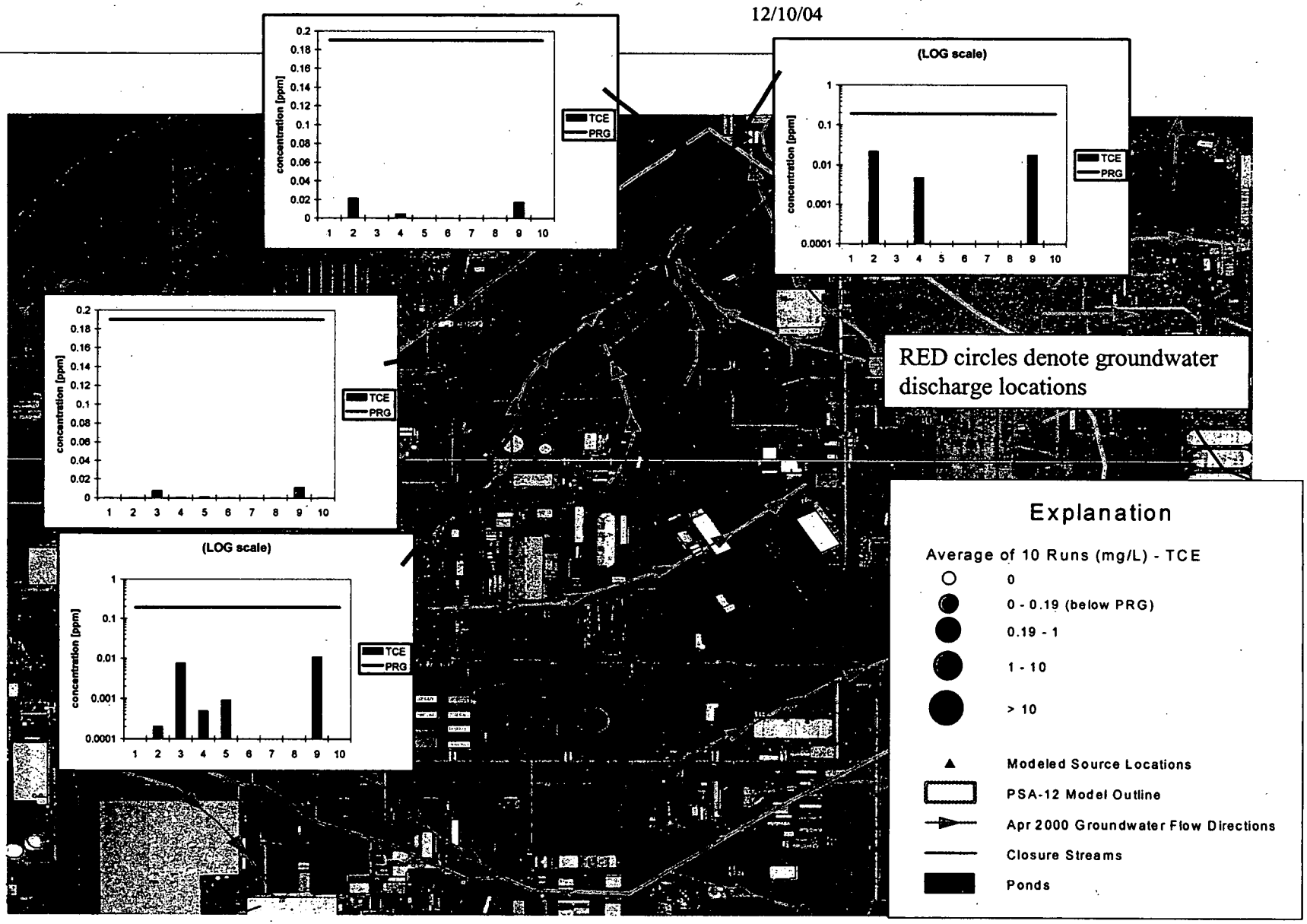

Figure E-2. PSA 12 – Simulated TCE Groundwater Concentrations at Discharge Cells

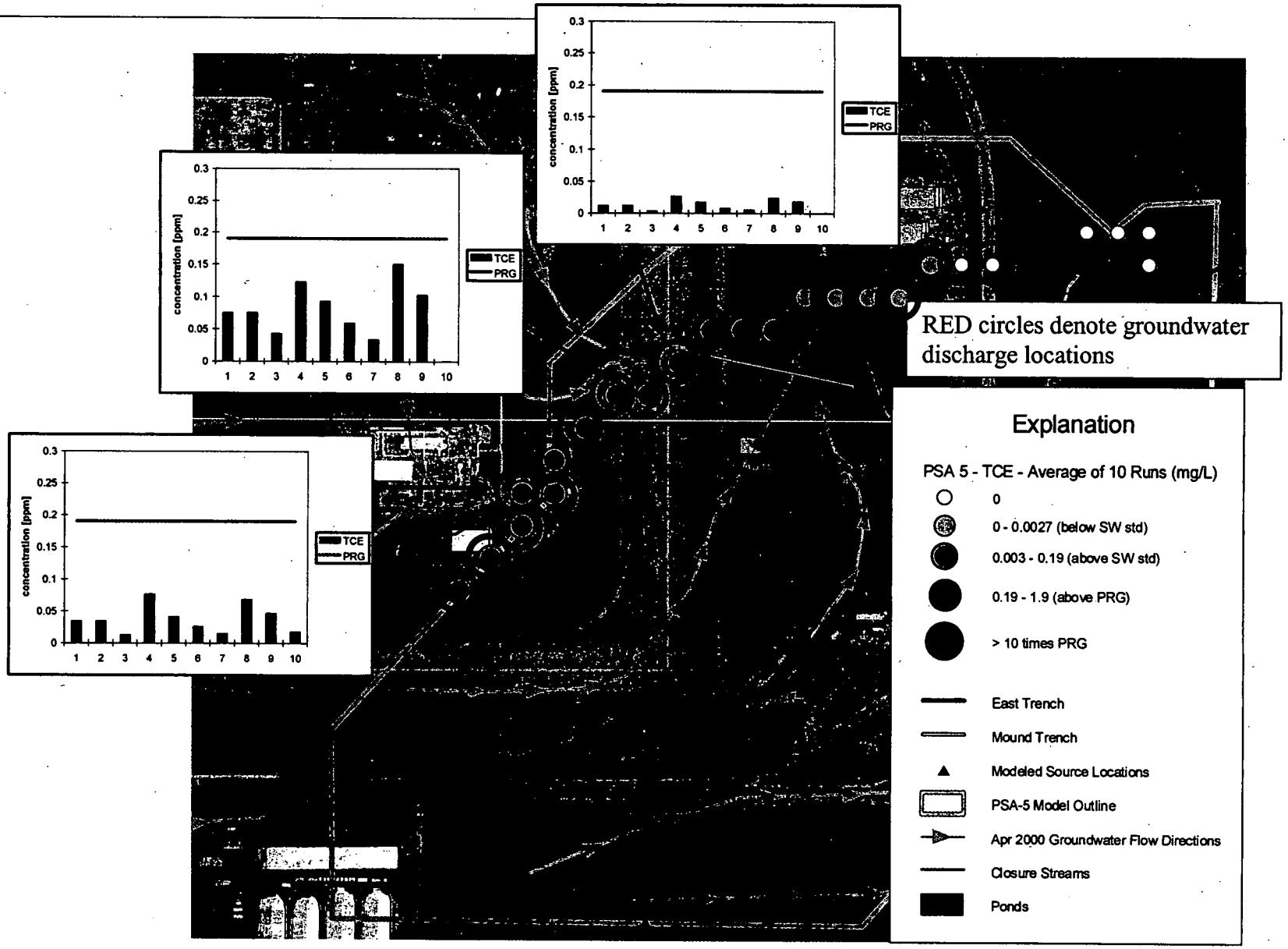

Figure E-3. PSA 5 – Simulated TCE Groundwater Concentrations at Discharge Cells

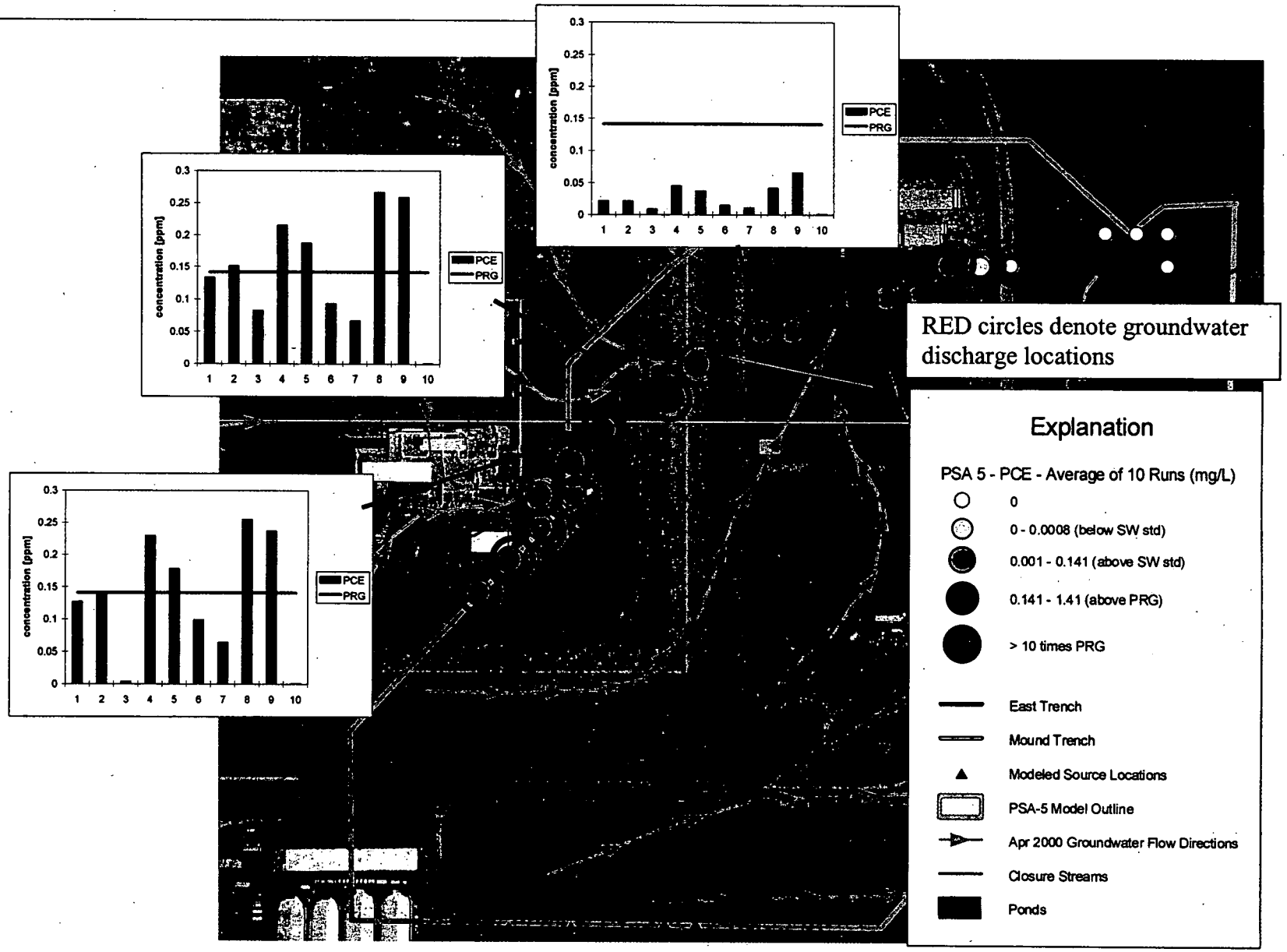

Figure E-4. PSA 5 – Simulated PCE Groundwater Concentrations at Discharge Cells

Groundwater IM/IRA
Appendix F

Flow Chart - Detail of Process to Analyze Data and Select an Action

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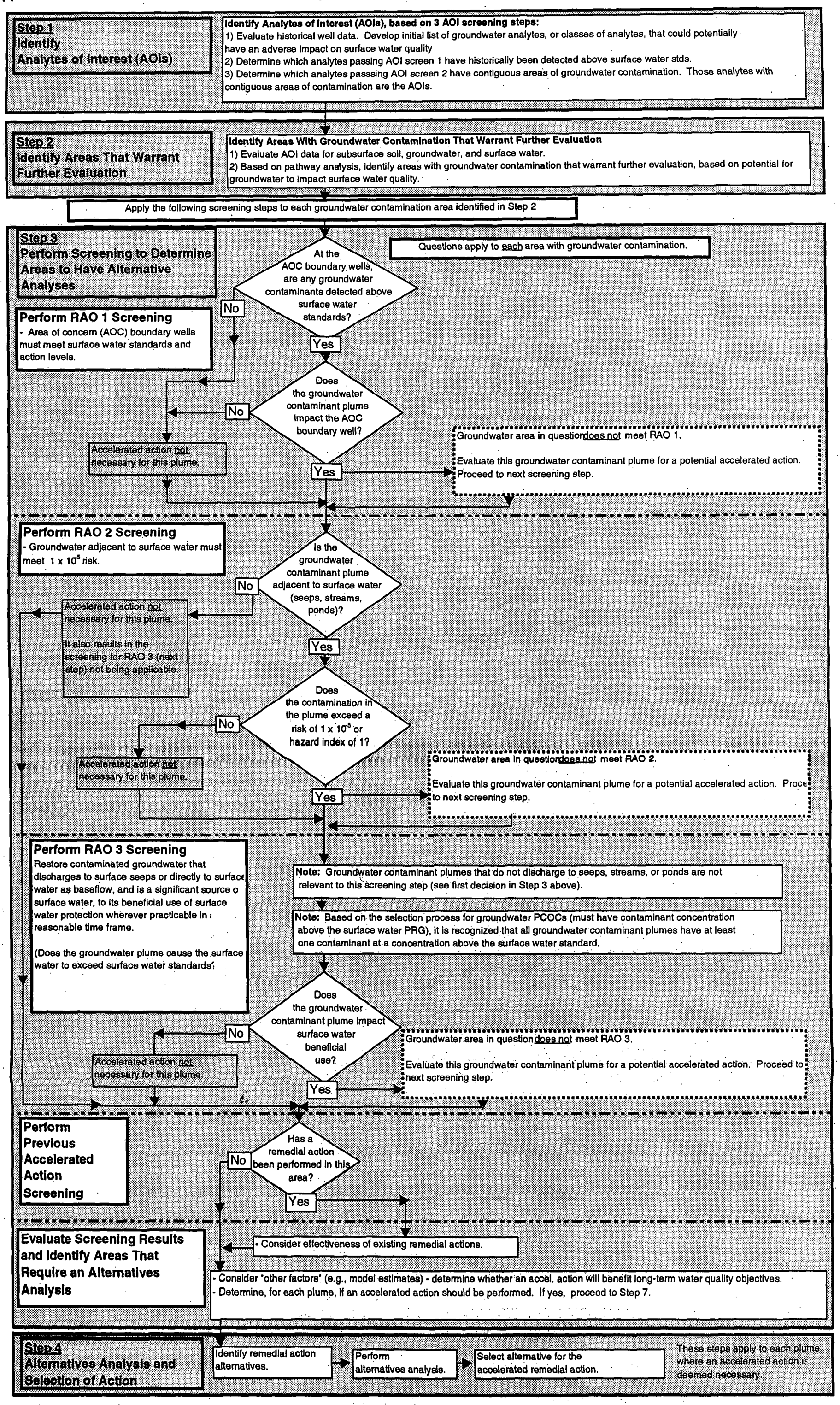
Appendix F. Flow Chart - Detail of Process to Analyze Data and Select an Action - Groundwater IM/IRA



21b

Groundwater IM/IRA
Appendix G

Evaluation of the Existing Mound Site Plume Collection System Extent

Appendix G – Evaluation of the Existing Mound Site Plume Collection System Extent

The Mound Site/Oil Burn Pit #2 Plume is located on the eastern side of the Rocky Flats Environmental Technology Site (RFETS) Industrial Area (IA), and east of the former Protected Area (PA) fence. This plume is believed to originate from the Mound Site area and the Oil Burn Pit #2 area and extends northward to South Walnut Creek with a component that heads northwest toward the former Building 991area. The plume previously discharged at less than 2 gallons per minute as seeps and subsurface flow into the South Walnut Creek drainage, primarily at seep SW059. The contaminants are primarily volatile organic compounds (VOCs), but radionuclides and naturally occurring metals below background levels have been detected as well. VOC concentrations exceed the Rocky Flats Cleanup Agreement (RFCA) groundwater action levels (ALS) within the plume and were above surface water action levels at seep SW059.

The contaminated water discharging from SW059 was previously collected and treated as part of the Operable Unit (OU) Surface Water Interim Measure/Interim Remedial Action (IM/IRA). The scope of the IM/IRA was reduced based on surface water results until the only source of contaminated groundwater collected was SW059. This water was collected and stored at the seep area, then transported for treatment at the Building 891 Water Treatment Facility. In 1998, the Mound Site Plume Collection and Treatment System was installed to collect and treat the entire Mound Site Plume, including the portion that daylighted at SW059.

During the design phase of the Mound Site Plume Treatment System, Site utility drawings showed a 235-foot-long french drain running roughly southwest-northeast near the western side of the collection system. No other details on the french drain were found. The system was believed to predate the PA fence and was possibly installed to drain the swampy ground east of Building 991 prior to installing the fence (see Figure G-1).

The collection system was installed from east to west. At the far western extent of the collection system, immediately adjacent to and within the perimeter roadway, the french drain was intersected, but not excavated. The french drain was approximately 18 inches in diameter and consisted of cobble-sized river rock wrapped in geotextile. The french drain was found at or near the claystone bedrock surface and below the fill material placed during construction of the PA fence. The amount of water collected by the french drain affected the stability of the excavation walls, causing local collapse (see Figure G-2).

Based on field investigations, the french drain alignment intersects SW059 and was the most likely cause of this seep. This feature explained the slightly different contaminants observed at SW059 with respect to the rest of the plume. This supported the belief that there were potentially two contaminant sources for the Mound Site Plume, including fill material placed during construction of the PA fence and the eastern road that may include soil from Individual Hazardous Substance Site (IHSS) 153 - Oil Burn Pit #2 (DOE 1997). At the time of system installation, it was believed that the trace amounts of radionuclides at SW059 might also result from within the PA.

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Figure G-1. Mound Site/Oil Burn Pit #2 Plume Collection System

(insert 8.5 x 11 color figure)

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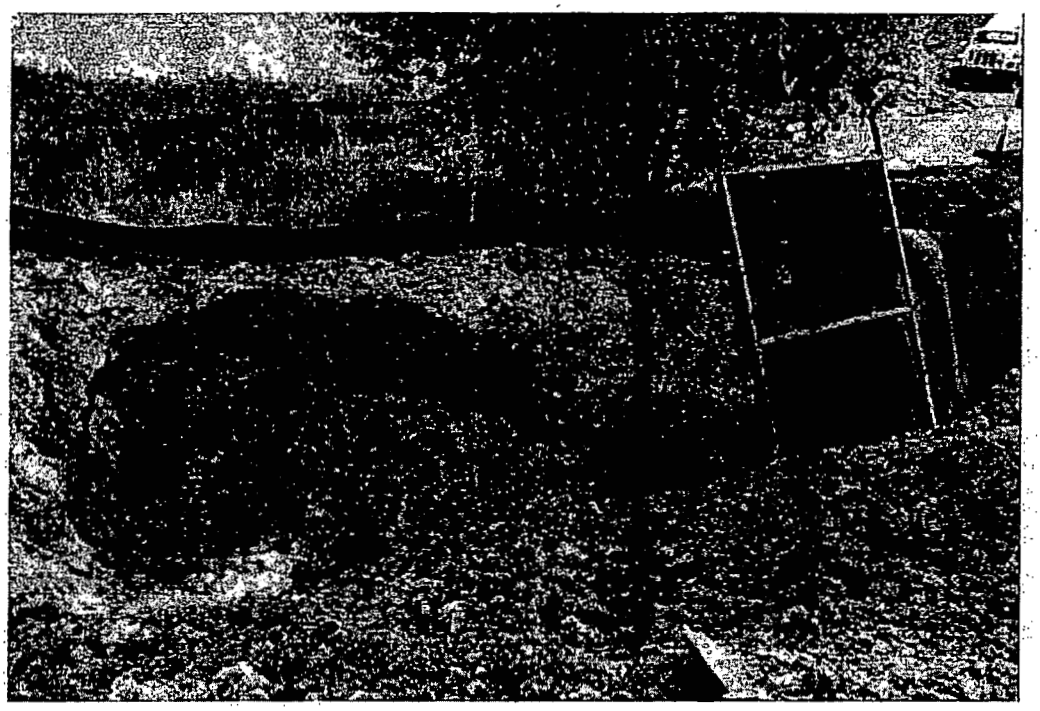

Figure G-2. Mound Site Plume Collection System Where It Intersected French Drain

1.1 Evaluation of French Drain Effectiveness

Very little water was encountered during installation of the Mound Site Plume Collection System until the french drain was intersected. While no flow measurements were taken, water was only observed in the collection trench during construction in the area of the french drain. Prior to system installation, flow rates at SW059 were approximately 0.5 gallons per minute (DOE, 1997). This amount is roughly what the system collected in 2003 (DOE, 2002), indicating that much of the flow is the result of water collected by the french drain, with the remaining quantity coming from the rest of the collection system.

The VOC results for water collected at SW059 and at the Mound Site Plume treatment system are shown in Table G-1.

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Table G-1. VOC Concentrations for SW059 and Mound Plume (in µg/L)

Analyte	SW059 Concentration Range	Mound Plume Treatment System Influent (at start-up)	Mound Plume Treatment System Concentration Range (calendar year 2003)	Groundwater Tier II Action Levels
Carbon Tetrachloride	3 - 120	57	73 – 104 D	5
Chloroform	5 - 25	23	19 - 21.4	100
Cis-1,2-Dichloroethene	NR	30	ND	70
1,2 Dichloroethane (total)	NR	26	ND - 0.39 J	5
1,1,1-Trichloroethane	NR	4.6	2 - 2.8	200
1,1-Dichloroethane	NR	1.6 J	ND - 1	3,650
1,1-Dichloroethene	NR	4	0.39 J - 2	7
Methylene Chloride	0.1 - 0.3	0.75 J	ND	5
Tetrachloroethene	1 - 21	35	22.6 - 31	5
Trichloroethene	5 - 71	64	31.4 - 38	5
Vinyl Chloride	0.7 - 3	1 J	ND - 0.81 J	2

D – diluted value

J – concentration is below detection limit for equipment

ND – not detected

NR – not reported

µg/L – micrograms per liter

In calendar year 2003, the upgradient groundwater plume concentrations included relatively low concentrations of VOCs. The highest VOC concentrations in well 15399 were 72.2 micrograms per liter (µg/L) cis-1,2-dichloroethene (DCE) and 106 µg/L of trichloroethene (TCE). Well 15499 had 107 µg/L TCE and 118 µg/l of tetrachloroethene (PCE). The two new upgradient wells, 91103 and 91203, were recently installed in the area of soil contamination associated with IHSS 153, Oil Burn Pit #2. Well 91203 also had relatively low concentrations of VOCs; the highest concentration was carbon tetrachloride (CT) at 126 µg/L. An additional well installed in the Oil Burn Pit #2 area (well 91103) had VOC concentrations two orders of magnitude higher than other upgradient wells with PCE at 18,100 µg/L and TCE at 10,800 µg/L.

The contaminant concentrations seen in the upgradient wells, as well as those from former seep SW059, correlate with what is currently seen in the groundwater collection system.

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1.2 Summary and Conclusions

While the purpose and extent of the french drain is not known, it apparently intersects some of the groundwater flow in the area of the PA fence, including the Oil Burn Pit #2 area, and potentially flow from within the PA. Based on the information from installation of groundwater systems at Rocky Flats, it is likely that some contaminated groundwater bypasses and underflows this french drain. However, based on the previous flow rate observed at SW059, and the amount of water discharged from the french drain during construction activities for the Mound Site Plume, the majority of the water in the area is captured by the existing system.

This evaluation demonstrates that the Mound Site Collection System fulfills the original objectives of the Mound Site Plume IM/IRA (DOE, 1997), which are:

- Intercept and treat contaminated groundwater, including seep SW059, at the distal end of the Mound Site Plume;
- Design and install a passive groundwater treatment system that, to the extent practicable, protects surface water and reduces the contaminant mass loading in surface water consistent with the Action Levels and Standards Framework for Surface Water, Groundwater, and Soil (ALF);
- Design the reactive metals treatment system and the barrier wall construction method to minimize the generation of low-level mixed waste and/or low-level waste; and
- Avoid depletion of waters to South Walnut Creek.

For these reasons, the combined Mound Site/Oil Burn Pit #2 Plume is captured and treated to the extent practicable, and an extension of the existing collection system is not required.

1.3 References

DOE, 1997. Final Mound Site Plume Decision Document, RF/RMRS-97-024, Rocky Flats Environmental Technology Site, Golden, Colorado, September.

DOE, 2002. First Five-Year Review Report for the Rocky Flats Environmental Technology Site, Golden, Colorado, July 2002.

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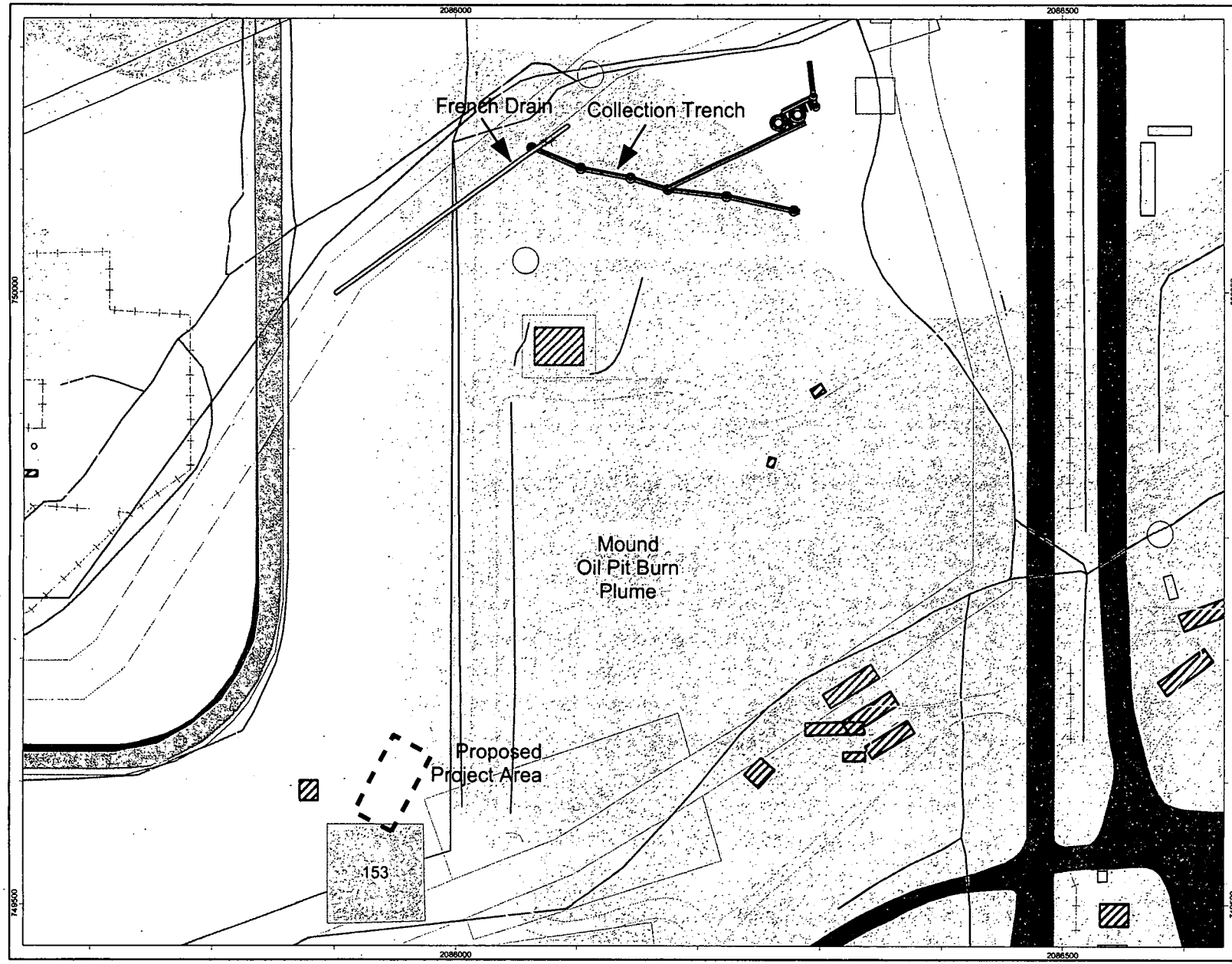

Rocky Flats Environmental Technology Site

Figure G-1

Mound Site/Oil Burn Pit #2 Collection System

- Break in Pipe
- French Drain
- Collection Trench
- Treatment Gallery
- Dirt Roads
- Trails
- Fence
- Streams
- Project Area
- Demolished Structure
- Standing Structure
- Paved Surface
- Lake
- IHSS 153
- Other IHSS
- UBCs
- PACS
- PACs NFA in 1992
- Composite VOC Plume
- Nitrate Plume

1:1,451
1 inch equals 120 feet

State Plane Coordinate Projection
Colorado Central Zone (3476)
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: CH2MHILL

Prepared for: KAISER+HILL COMPANY

MAP ID: GIS Dept. (303) 966-7707 June 23rd, 2004

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Groundwater IM/IRA
Appendix H

VOC Strategy for 903 Pad/Ryan's Pit Plume Area

Appendix H – VOC Strategy for 903 Pad/Ryan's Pit Plume Area

1.1 Background and Objectives

The 903 Pad area was used to store drums that contained radioactively contaminated oils and volatile organic compounds (VOCs) from 1958 to 1967. The liquid in the drums was primarily lathe coolant and/or carbon tetrachloride (CT). However, hydraulic oils, vacuum pump oils, trichloroethene (TCE), tetrachloroethene (PCE), silicone oils, and acetone still bottoms and other liquids were also stored in these drums. When leaking drums were noted in 1964, the contents of the leaking drums were transferred to new drums. Cleanup operations began in 1967. It was suspected that approximately 420 drums leaked to some degree. The total amount of leaked material was estimated at approximately 5,000 gallons of contaminated liquid that contained approximately 86 grams of plutonium (K-H, 2000).

The remedial action for the 903 Pad was completed in October 2003 with the removal of contaminated soil to a depth of at least 3 feet across the area. While the objective of the remedial action was to remove radiologically contaminated soil, it was noted that most of the excavated material was also contaminated with VOCs. The areas where high concentrations of VOCs were excavated are shown on Figure H-1. This remedial action at the 903 Pad showed that more than 86 grams of plutonium was present as a result of leaks from the drums.

Preremedial action borehole and soil gas data also indicate the presence of subsurface VOC-contaminated soil. Based on the borehole data, VOC-contaminated soil is found in two zones: near surface soil (less than 6 feet below ground surface), and deeper soil near or at the bedrock surface.

Areas where subsurface VOC-contaminated soil may be present were identified using historical borehole and soil gas data. In addition, the VOC data collected for the waste containers were linked back to the excavated cell and used to indicate what was previously at that location. While this material has been removed, it indicates areas where higher concentrations of VOCs may remain. These data were overlain with the recent remedial action excavation depths to determine what may still remain as a potential source of groundwater contamination.

The contaminants of concern (COCs) used for this study were PCE, TCE, and CT because these are the primary groundwater contaminants in this area. Additional VOCs, including chloroform (CF), toluene, methylene chloride (MC), and acetone are also present.

1.2 Investigation Areas

Based on this information, five areas were identified for further investigation to determine whether if there are possible impacts to groundwater (Figure H-1). These areas are listed in order of priority as follows:

- Area 1 - Soil gas anomaly, VOC contamination in upper 4 feet (removed during remedial action) and in an area with high VOCs during soil remediation. There is known VOC contamination at depth (greater than 25 feet), but at low concentrations (PCE at 110 micrograms per kilogram (μg/kg), TCE at 27 μg/kg).

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- Area 2 - Two cells with elevated VOC contamination in excavated material. This area was not deeply excavated.
- Area 3 - One cell with elevated VOC contamination in excavated material. This area was excavated to a depth greater than 4 feet.
- Area 4 - Soil gas anomaly, VOC contamination at depth (23 to 27 feet). Excavated material at this location contained moderate concentrations of VOCs.
- Area 5 - South of the 903 Pad, VOCs in near-surface soil were identified.

The investigation areas are roughly correlated with the VOC-contaminated groundwater plume in this area and confirm the modeling results that show this area is not a major contributor to groundwater contamination. The overall shape of the plume is controlled more by the bedrock surface and may be a result of the lower concentrations of VOCs in soil that were present prior to remediation.

1.3 Investigation Approach

The areas will be investigated in order of priority as listed above. The approach will be as follows:

- Identify depth to bedrock in the investigation areas. Evaluate bedrock surface and slope to determine likely areas for VOCs to accumulate.
- Sample the investigation areas as follows:
  - Area 1 – 11 sampling locations that augment the previous boreholes in this area;
  - Areas 2 and 3 – 3 sampling locations each;
  - Area 4 – 5 sampling locations; and
  - Area 5 – 3 sampling locations.
  - Additional stepout samples will be added as necessary to define the areas of VOC contamination.
  - If no VOC contamination is found at an investigation area, the area will be removed from further evaluation.
- Collect soil samples for VOC analyses either from the ground surface or bottom of the 903 Pad excavated areas, whichever is deeper, to a depth of 6 feet to evaluate the potential upper contamination. Samples will be collected using a Geoprobe. Sample intervals will be as described in the Industrial Area and Buffer Zone Sampling and Analysis Plan (DOE, 2004).
  - The interval from 6 feet to bedrock will be cored and visually inspected for staining or other signs of contamination. A photoionization detector (PID) or similar instrument will be used to monitor the core to detect any additional VOC contamination if present. VOC samples will be collected for core intervals with stained soil or elevated PID readings.
  - The depth to groundwater will be noted as possible.

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- Collect VOC samples for the sample intervals immediately above and below the bedrock surface. If the bedrock surface falls within one sample interval, then two samples will be collected within that interval and the next lower sample interval designation will be used for the bedrock sample.

1.4 Potential Source Removal Actions

Based on the depth of excavation across the 903 Pad, most of the shallow VOC-contaminated soil is expected to already have been removed. The results of the investigation will determine whether additional actions are required to minimize impacts to surface water from groundwater in this area.

The preliminary remediation approach is as follows:

- If VOC contamination is present above action levels (ALs) in the upper 3 feet, a removal action will be triggered.
- If VOC contamination is present above ALs at elevations greater than 3 feet below final grade, and if action is indicated by the Subsurface Soil Risk Screen, then HRC® (an amendment used in in-situ enhanced biodegradation) or other appropriate material will be inserted at this location and depth at the manufacturer's recommended application rate. Based on experience using this type of approach at the Property Utilization and Disposal (PU&D) Yard, this will be a one-time application. At this location, HRC® has persisted in the environment for over 3 years.

References

DOE, 2004. Industrial Area and Buffer Zone Sampling and Analysis Plan, Modification 1, Rocky Flats Environmental Technology Site, Golden, Colorado, May.

K-H, 2000. Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone, RF/RMRS-99-427.UN, Rev.-1, Rocky Flats Environmental Technology Site, Golden, Colorado, June.

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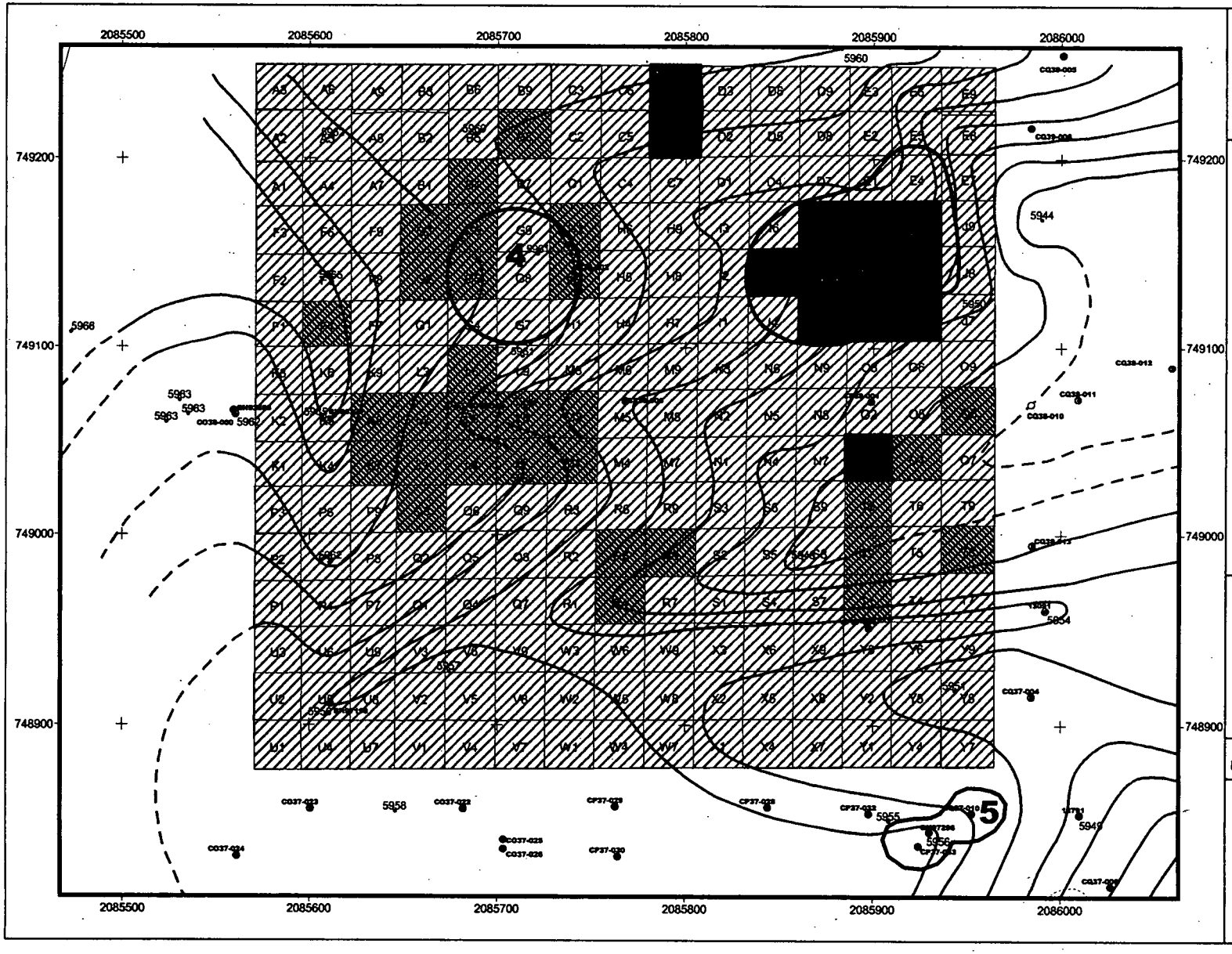

Figure H-1
903 Pad Lip Remediation
VOC Results over Background, Confirmation Cells Excavated to a Depth of > 4 Feet with Waste Shipments > 1000 ug/mg VOC and Revised Bedrock Elevation

KEY

VOC Analyte by Sample Type > Background

- 1,1,2,2-Tetrachloroethane
- 2-Butanone
- Acetone
- Benzene
- Bromomethane
- Carbon Tetrachloride
- Chlorobenzene
- Chloroform
- Chloromethane
- Ethylbenzene
- Methylene chloride
- Naphthalene
- Styrene
- Tetrachloroethene
- Toluene
- Trichloroethene
- Xylene

Bedrock Elevation Contour
Streams
Dirt Roads
Demolished
Existing
Asphalt
Demolished
Standing

Composite VOCs in Waste Shipments by Confirmation Cell
1000 - 1000000 ug/mg

Excavation Depth (Depth to Clean Confirmation Sample)
> 4 Feet

N
W E
S

0 25 50 75 100 Feet

Scale = 1:600
1" = 50'

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:

[redacted]

Prepared for:

KAISER-HILL COMPANY

File: [illegible]
Layout: RADMS Layout (11 X 17)
Date: 8/09/2004

Groundwater IM/IRA
Appendix I

List of Applicable or Relevant and Appropriate Requirements (ARARs)

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CLEAN AIR ACT (CAA) (42 U.S. Code [USC] 7401 et. seq.)			
Requirement	**Citation**	**Type**	**Comment**
COLORADO AIR QUALITY CONTROL COMMISSION (CAQCC) REGULATIONS	**5 Code of Colorado Regulations (CCR) 1001 (40 Code of Federal Regulations [CFR] 52, Subpart G)**		
Emission Control Regulations for Particulates, Smokes, Carbon Monoxide, and Sulfur Oxides	**CAQCC Reg. No. 1 (5 CCR 1001-3)**		
• Fugitive Particulate Emissions -Construction Activities -Storage and Handling of Material -Haul Roads -Haul Trucks -Demolition Activities -Sandblasting Operations	Section III.D III.D.2(b) III.D.2(c) III.D.2(e) III.D.2(f) III.D.2(h) III.D.2(j)	A	Every activity shall employ control measures and operating procedures that are technologically feasible and economically reasonable and reduce, prevent, and control fugitive particulate emissions (control plans, use of control equipment, watering, etc.).
Air Pollutant Emission Notices (APENs), Construction Permits and Fees, Operating Permits, Including the Prevention of Significant Deterioration (PSD)	**CAQCC Reg. No. 3 (5 CCR 1001-5)**		
• APEN Requirements	Part A, Section II	A, C	An APEN shall be filed with the Colorado Department of Public Health and Environment (CDPHE) prior to construction, modification, or alteration of, or allowing emissions of air pollutants from any, activity. Certain activities are exempt from APEN requirements per specific exemptions listed in the regulation.
• Construction Permits, Including Regulations for PSD	Part B		

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered

CLEAN AIR ACT (CAA) (42 U.S. Code [USC] 7401 et. seq.)			
Requirement	**Citation**	**Type**	**Comment**
-Construction Permits	Part B, Section III	A, C	Construction permits are not required for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) activities; however, substantive requirements that would normally be associated with construction permits will apply. Also, fuel-fired equipment (generators, compressors, etc.) associated with these activities may require permitting.
-Compliance and Reporting	61.94	C/L	Compliance with the standard shall be determined by calculating the highest Effective Dose Equivalent (EDE) to any member of the public at any off-site point where there is a residence, school, business, or office.

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered

FEDERAL WATER POLLUTION CONTROL ACT (aka Clean Water Act [CWA])(33 USC 1251 et. seq.)			
Requirement	**Citation**	**Type**	**Comment**
COLORADO BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER	**5 CCR 1002-31**		
• Process for Assigning Standards and Granting, Extending, or Removing Temporary Modifications	31.7	C/L	The Point of Compliance (POC) for surface water will be at the current surface water POCs identified in the Rocky Flats Cleanup Agreement (RFCA) Attachment 5. While changes to standards, temporary modifications, and the use of mixing zones are not anticipated for this Interim Measure/Interim Remedial Action (IM/IRA) in relation to the surface water POC, performance monitoring may take these requirements into consideration.
• Mixing Zones	31.10		
• Basic Standards Applicable to Surface Waters of the State	31.11		
CLASSIFICATION AND NUMERIC STANDARDS FOR THE SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN, REPUBLICAN RIVER BASIN, AND SMOKY HILL RIVER BASIN	**5 CCR 1002-38**		
• Classification Tables	38.6	C/L	Lists use classification and parameters for the Segments 4a, 4b, and 5 of Big Dry Creek (Woman and Walnut Creeks on RFETS).
COLORADO BASIC STANDARDS FOR GROUNDWATER	**5 CCR 1002-41**	C/L	
• POC	41.6	C/L	The POC for assessment and monitoring of groundwater quality is described and shown in the IM/IRA.

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered

FEDERAL WATER POLLUTION CONTROL ACT (aka Clean Water Act [CWA])(33 USC 1251 et. seq.)			
Requirement	**Citation**	**Type**	**Comment**
SITE-SPECIFIC WATER QUALITY CLASSIFICATIONS AND STANDARDS FOR GROUNDWATER	**5 CCR 1002-42**		
Rocky Flats Area, Jefferson and Boulder Counties	42.7(1)	C/L	
U.S. DEPARTMENT OF ENERGY (DOE) COMPLIANCE WITH FLOODPLAIN/WETLANDS ENVIRONMENTAL REVIEW REQUIREMENTS	**10 CFR 1022**		
• Floodplain/Wetlands Determination • Floodplain/Wetlands Assessment • Applicant Responsibilities	10 CFR 1022.11 10 CFR 1022.12 10 CFR 1022.13	A/L	
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)	**33 USC 1342; 40 CFR 122**		
• Stormwater Permits for Construction Activities	40 CFR 122.26	A/L	On-site remedial actions do not require permits, but projects outside the Industrial Area (IA) that involve stormwater discharges must meet substantive requirements for a general NPDES permit.
• General Permits	40 CFR 122.28	A/L	

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered

NATURAL RESOURCE AND WILDLIFE PROTECTION LAWS			
Requirement	**Citation**	**Type**	**Comment**
ENDANGERED SPECIES ACT (ESA)	**16 USC 1531 et seq.**		
• Early consultation	50 CFR 402.11	A/L	Identify and minimize early in the planning stage of an action any potential conflicts between the action and federally listed species.
• Biological assessment -Purpose -Preparation Requirements -Request for Information -Director's Response -No Listed Species or Critical Habitat Present -Listed Species or Critical Habitat Present -Verification of Current Accuracy of Species List -Contents -Identical/Similar to Previous Action -Permit Requirements -Completion Time -Submission of Biological Assessment -Use of Biological Assessment	50 CFR 402.12	A/L	DOE will evaluate the potential effects of the action on listed species and critical habitat and determine whether any such species or habitat are likely to be adversely affected by the projects in determining whether formal consultation or a conference is necessary.
Interagency cooperation	**50 CFR 402**		

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NATURAL RESOURCE AND WILDLIFE PROTECTION LAWS			
Requirement	**Citation**	**Type**	**Comment**
• Informal Consultation	50 CFR 402.13	A/L	Optional process that includes all discussions, correspondence, and so forth between the U.S. Fish and Wildlife Service (USFWS) and DOE to assist in determining whether formal consultation or a conference is required. If, during this step, DOE determines, with the written concurrence of the USFWS, that the action is not likely to adversely affect listed species or critical habitat, the consultation process is terminated and no further action is necessary. Otherwise, formal consultation shall occur.
• Formal Consultation	50 CFR 402.14	A/L	Results of informal or formal consultation shall be evaluated in project implementation plans. The RFCA Parties shall consult on any changes to any project that may be necessary.
MIGRATORY BIRD TREATY	**16 USC 701-715**		
• Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants	50 CFR 10	A/L	Projects shall be planned and implemented to prevent or minimize contact with listed birds and nests.
COLORADO NONGAME, ENDANGERED, OR THREATENED SPECIES CONSERVATION ACT	**Colorado Revised Statutes (CRS) 33-1-115, 33-2-101 to 33-2-107**		
• Compliance with the Colorado Nongame Wildlife, including Endangered Species	CRS 33-2-104 CRS 33-2-105	A/L	Project implementation plans will be evaluated regarding whether they may result in any prohibited taking or possession of any species or subspecies of wildlife appearing on the list of wildlife indigenous to the State of Colorado determined to be endangered within the State. The RFCA Parties shall consult on any changes to any project that may be necessary.

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered

NATURAL RESOURCE AND WILDLIFE PROTECTION LAWS			
Requirement	**Citation**	**Type**	**Comment**
FEDERAL NOXIOUS WEED ACT	**Pub. L. 93-629; 7 USC 2814 et. seq.**		
• Management of Undesirable Plants on Federal Lands • Duties of Federal Agencies	7 USC 2814 (a)(3), (a)(4), (c)(1), (c)(2)	A	Project implementation plans will be evaluated regarding control or contain actions needed for undesirable plant species targeted under any State agency cooperative agreements.
COLORADO NOXIOUS WEED ACT	**CRS 35-5.5-101 et. seq.**		
• Duty to Manage Noxious Weeds	Section 104	A	Project implementation plans will be evaluated regarding use of integrated methods to manage noxious weeds if the same are likely to be materially damaging to the land of neighboring landowners.
• Cooperation with Federal and State Agencies	Section 111	A	The local governing bodies in Colorado are authorized to enter into cooperative agreements with federal and state agencies for the integrated management of noxious weeds within their respective territorial jurisdictions. The Jefferson County Noxious Weed Management Plan establishes the countywide strategy for the management, control, and eradication of noxious weeds in the County.

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered

SOLID WASTE DISPOSAL ACT (aka: Resource Conservation and Recovery Act) [42 USC 6901 et. seq.] SUBTITLE C: HAZARDOUS WASTE MANAGEMENT [Colorado Hazardous Waste Act (CRS 25-15-101 to 217]			
Requirement	**Citation**	**Type**	**Comment**
HAZARDOUS WASTE DISPOSAL SITES AND FACILITIES	**6 CCR 1007-3**		
Identification and Listing of Hazardous Wastes	6 CCR 1007-3, 261 (40 CFR 261)	A	All remediation waste will be characterized to determine a hazardous waste classification.
Generator Standards	6 CCR 1007-3 Part 262 (40 CFR Part 262)		
• Hazardous Waste Determinations	.11	A/C	Persons who generate solid wastes are required to determine if the wastes are hazardous according to 6 CCR 1007-3 Parts 261, 267, 279 (40 CFR Parts 261, 266, and 279).
• Hazardous Waste Accumulation Areas	.34 (a)(1)(i), (ii), (iv, excluding A & B); (a)(3); (a)(4); (c)(1)	A	Persons who accumulate hazardous waste in containers or tanks must manage the waste in a manner that protects human health and the environment.
General	6 CCR 1007-3, Part 265, Subpart A (40 CFR 265, Subpart A)		
• Waste Analysis	.13 (a)	A	The owner/operator of a facility that stores, treats, or disposes of waste must verify the waste has been characterized adequately.
• Security	.14	A/L	The owner/operator of a facility must prevent unauthorized access.
• General Inspection Requirements	.15 (a), (c)	A/L	The owner/operator of a facility must inspect for malfunctions, deteriorations, and releases, and must remedy deficiencies.

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SOLID WASTE DISPOSAL ACT (aka: Resource Conservation and Recovery Act) [42 USC 6901 et. seq.] SUBTITLE C: HAZARDOUS WASTE MANAGEMENT [Colorado Hazardous Waste Act (CRS 25-15-101 to 217]			
Requirement	**Citation**	**Type**	**Comment**
• Personnel Training Requirements	.16 (a), (b), (c)	A/C	Personnel must be trained.
• General Requirements for Ignitable, Reactive, or Incompatible Wastes	.17 (a), (b)	A/C	Wastes will be managed to prevent accidental ignition or reaction of ignitable or reactive waste, or the mixing of incompatible waste.

A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR; TBC - To Be Considered